Gilia penstemonoides M.E. Jones (Black Canyon gilia): A Technical Conservation Assessment

Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project

February 9, 2004

Brenda Beatty, William Jennings, and Rebecca Rawlinson
CDM, 1331 17th Street, Suite 1100, Denver, Colorado 80202

Peer Review Administered by
Center for Plant Conservation

Beatty, B.L., W.F. Jennings, and R.C. Rawlinson (2004, February 9). *Gilia penstemonoides* M.E. Jones (Black Canyon gilia): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/giliapenstemonoides.pdf [date of access].

ACKNOWLEDGEMENTS

We acknowledge several botanists and land management specialists for providing helpful input, including Gay Austin, Robin Bingham, Beth Burkhart, Denise Culver, Dean Erhard, and Barry Johnston. Natural Heritage Programs and herbaria within USFS Region 2 supplied current occurrence records of this species from their databases and collections. We thank William Jennings (photograph) and Tracy Wager (technical illustration) for permission to use their *Gilia penstemonoides* images. Funding for this document was provided by U.S. Forest Service, Rocky Mountain Region (Region 2) contract 53-82X9-1-123.

AUTHORS' BIOGRAPHIES

Brenda L. Beatty is a senior ecologist and environmental scientist with CDM Federal Programs Corporation. Ms. Beatty has over 22 years of professional experience in the environmental industry and has provided technical support for wetlands delineations, ecological surveys, threatened and endangered species surveys, ecological sampling, and ecological risk assessments throughout the country. Her experience in ecology has been used to develop species assessments, characterize biotic communities, identify sensitive ecosystems, estimate wildlife use areas, identify potential habitat for threatened and endangered species, and locate threatened and endangered species. Ms. Beatty received her B.A. in Environmental Science from California State College of Pennsylvania in 1974 and her M.S. in Botany/Plant Ecology from Ohio University in 1976.

William F. Jennings is a consultant specializing in studies of rare, threatened, or endangered plant species in Colorado. Mr. Jennings regularly conducts surveys for threatened species throughout the state and is responsible for discovering several new populations of many species. His botanical emphasis is in the floristics and taxonomy of native orchids. He is the author and photographer of the book *Rare Plants of Colorado* (1997) published by the Colorado Native Plant Society and a co-author of the *Colorado Rare Plant Field Guide* (1997). Mr. Jennings received his B.S. and M.S. in Geology from the University of Colorado, Boulder.

Rebecca C. Rawlinson is an ecologist with CDM Federal Programs Corporation. Ms. Rawlinson's work has focused on the control of non-native plant invasions, conservation of native plant species, and restoration of native plant communities. She has participated in demographic monitoring of rare native plants, performed vegetation mapping and surveys, and assisted in restoration projects in a variety of temperate ecosystems. Ms. Rawlinson received her B.S. in Natural Resources from Cornell University in 1997 and her M.A. in Plant Ecology from the University of Colorado, Boulder in 2002.

COVER PHOTO CREDIT

Gilia penstemonoides (Black Canyon gilia). Photograph by William Jennings. Reprinted with permission of the photographer.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *GILIA PENSTEMONOIDES*

Status

Gilia penstemonoides (Black Canyon gilia) is an endemic species with populations located in western and west-central Colorado. Of the 28 occurrences of *G. penstemonoides* in Region 2 of the U.S. Forest Service, 14 occurrences are on U.S. National Park Service lands, eight occurrences are on U.S. Forest Service lands, five occurrences are on U.S. Bureau of Land Management lands, and one occurrence is on private land.

The Global Heritage Status Rank for *Gilia penstemonoides* is G3, or vulnerable (NatureServe 2003). The Colorado Natural Heritage Program has ranked *G. penstemonoides* S3, or vulnerable (vulnerable to extirpation; endangered or threatened in the state) This gilia is not currently designated a sensitive species by the U.S. Forest Service Region 2 (U.S. Forest Service 2003) or the Colorado Bureau of Land Management (U.S. Bureau of Land Management 2000).

Primary Threats

Gilia penstemonoides is a perennial species that grows in crevices and on small ledges of steep canyon walls and cliffs. Little is known about the current abundance or ecological requirements of this species. The number of documented occurrences of this species is low, but the distribution within its range may be underestimated.

Threats to the long-term persistence of *Gilia penstemonoides* populations or habitats likely differ for each of the 28 occurrences. The most significant threats to the eight occurrences of *G. penstemonoides* on National Forest System lands probably include non-native plant invasion, recreational activities (e.g., rock climbing), global environmental changes, and hybridization. Populations at cliff bases or cliff tops near roads, trails, rock-climbing areas, campgrounds, or reservoirs are likely at higher risk from the detrimental effects of land use activities and non-native plant invasion.

Primary Conservation Elements, Management Implications, and Considerations

The lack of information regarding the colonizing ability, current distribution and abundance, adaptability to changing environmental conditions, sexual and vegetative reproductive potential, and genetic variability of *Gilia penstemonoides* makes it difficult to predict the species' vulnerability. Features of *G. penstemonoides* biology that may be important to consider when addressing conservation of this species (i.e., key conservation elements) include its specialization on cliff habitats, possible poor competitive abilities, preference for suitable crevices within its cliff environments, potential reliance on adequate moisture availability, possible need for water movement to disperse seeds, scattered distribution of both individuals and populations, susceptibility to erosion and other cliff face disturbances, possible outcrossing needs requiring efficient pollination, and apparently low reproductive success. Priority conservation tools for this species may include monitoring the effects of current U.S. Forest Service Region 2 land-use practices and management activities, reducing any human-related threats to existing high-risk populations, assessing population trends, and monitoring and assessing the effects of environmental fluctuations. Additional key conservation tools may include surveying high probability habitat for new populations, preventing non-native plant invasions, studying demographic parameters and reproductive ecology, and assessing the effects of future management activities or changes in management direction. Identifying high-quality populations and populations that may be immediately threatened, monitoring population trends, understanding the effects of environmental fluctuations, surveying for new populations, and studying basic biological traits are priorities of future research studies of *G. penstemonoides* in Region 2.

Table of Contents

EDITOR: Beth Burkhart, USDA Forest Service, Rocky Mountain Region

LIST OF TABLES AND FIGURES

Tables:

Figures:

Introduction

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), U.S. Department of Agriculture Forest Service (USFS). *Gilia penstemonoides* is the focus of an assessment because it is an uncommon species that may be considered for sensitive species status in USFS Region 2 (U.S. Forest Service 2003). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a regional forester because of significant current or predicted downward trends in population numbers, density, or habitat capability that would reduce the existing distribution of that species (U.S. Forest Service 1995). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Gilia penstemonoides* throughout its range, all of which is in USFS Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations but to provide the ecological background upon which management must be based. While the assessment does not provide management recommendations, it does focus on the consequences of changes in the environment that may result from management (i.e., management implications).

Scope and Information Sources

The *Gilia penstemonoides* species assessment examines the biology, ecology, conservation status, and management of this species with specific reference to its geographic and ecological characteristics in the USFS Rocky Mountain Region. Where literature used to produce this species assessment originated from investigations outside the region (e.g., studies of related species), this document placed that literature in the ecological and social contexts of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *G. penstemonoides* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis but placed in a current context.

In producing the assessment, an extensive literature search was performed to obtain all material focusing on *Gilia penstemonoides*, as well as information on related species and on the geographical and environmental context of this species. We reviewed refereed literature (e.g., published journal articles), non-refereed publications (e.g., unpublished status reports), theses and dissertations, data accumulated by resources management agencies (e.g., Natural Heritage Program [NHP] element occurrence records), and regulatory guidelines (e.g., USFS Forest Service Manual). Visits were not made to every herbarium with specimens of this species, but specimen label information provided by herbarium staff and available in NHP element occurrence records was included. Additionally, we incorporated information from studies of closely-related *Gilia* species or *Gilia* species in USFS Region 2 or adjacent areas; we avoided extrapolating from studies of unrelated *Gilia* species or *Gilia* species of drastically different environmental contexts. While the assessment emphasizes refereed literature because this is the accepted standard in science, non-refereed publications and reports are used extensively in this assessment because they provide information unavailable elsewhere. These unpublished, non-refereed reports are regarded with greater skepticism, and all information is treated with appropriate uncertainty.

Treatment of Uncertainty

Science represents a rigorous, synthetic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct critical experiments in the ecological sciences, and often observations, inference, good thinking, and models must be relied on to guide the understanding of ecological relations. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent the strongest approach to developing knowledge, alternative methods (modeling, critical assessment of observations, and inference) are accepted approaches to understanding features of biology.

Because of a lack of extensive experimental research efforts concerning *Gilia penstemonoides*, this assessment report relies heavily on the personal observations of botanists and land management specialists from throughout the range of this species. Much of the knowledge about the biology and ecology of *G. penstemonoides* is based on the observations of a few researchers (Harmon and Grey 1980, Peterson 1981, Grey 1982), Colorado Natural Heritage Program botanists (D. Culver personal communication 2003), other botanists who submitted occurrence records to the Colorado NHP (R. Bingham personal communication 2003, Colorado Natural Heritage Program 2002), and USFS resource management specialists (G. Austin personal communication 2002, D. Erhard personal communication 2002, B. Johnston personal communication 2003). Sections about the basic biology and habitat characteristics of this species are based largely on the unpublished, non-refereed research works from the early 1980s. When information presented in this assessment is based on our personal communications with a botanist, we cite those sources as "personal communication" Unpublished data (e.g., NHP element occurrence records and herbarium records) were also important in estimating the geographic distribution and describing habitat of this species. These data required special attention because of the diversity of persons contributing to the records, the variety of methods used to collect the data, and unverified historical information.

We also incorporated information, where available, from other *Gilia* species endemic to USFS Region 2 or adjacent states to formulate this assessment. Any comparisons are not meant to imply that *G. penstemonoides* is biologically identical to these other species, but they represent an effort to hypothesize about *potential* characteristics of this species. We avoided extrapolating from studies of unrelated *Gilia* species or *Gilia* species of drastically different environmental contexts. The biology, ecology, and conservation issues presented for this species in USFS Region 2 are based on inference from these published and unpublished (e.g., personal communications) sources. We clearly noted when we were making inferences based on the available knowledge to augment or enhance our understanding of *G. penstemonoides*.

Publication of Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they will be published on the USFS Region 2 World Wide Web site. Placing documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, it facilitates revision of the assessments, which will be accomplished based on guidelines established by USFS Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Gilia penstemonoides is an endemic species known from 28 occurrences within five western Colorado counties (**Figure 1**). This section describes the management status, existing regulatory mechanisms, and biological characteristics of the species.

Management and Conservation Status

Federal status

The Endangered Species Act of 1973 was passed to protect plant and animal species placed on the threatened or endangered list (U.S. Fish and Wildlife Service 1973). The listing process is based on population data and is maintained and enforced by the U.S. Fish and Wildlife Service (USFWS). In 1980, *Gilia penstemonoides* was ranked as a Category 2 species (taxa for which proposal as endangered or threatened is appropriate, but conclusive data on biological vulnerability and threats are not currently available) (U.S. Fish and Wildlife Service 1980). In 1993, the status of *G. penstemonoides* was changed to Category 3C (taxa that are no longer being considered

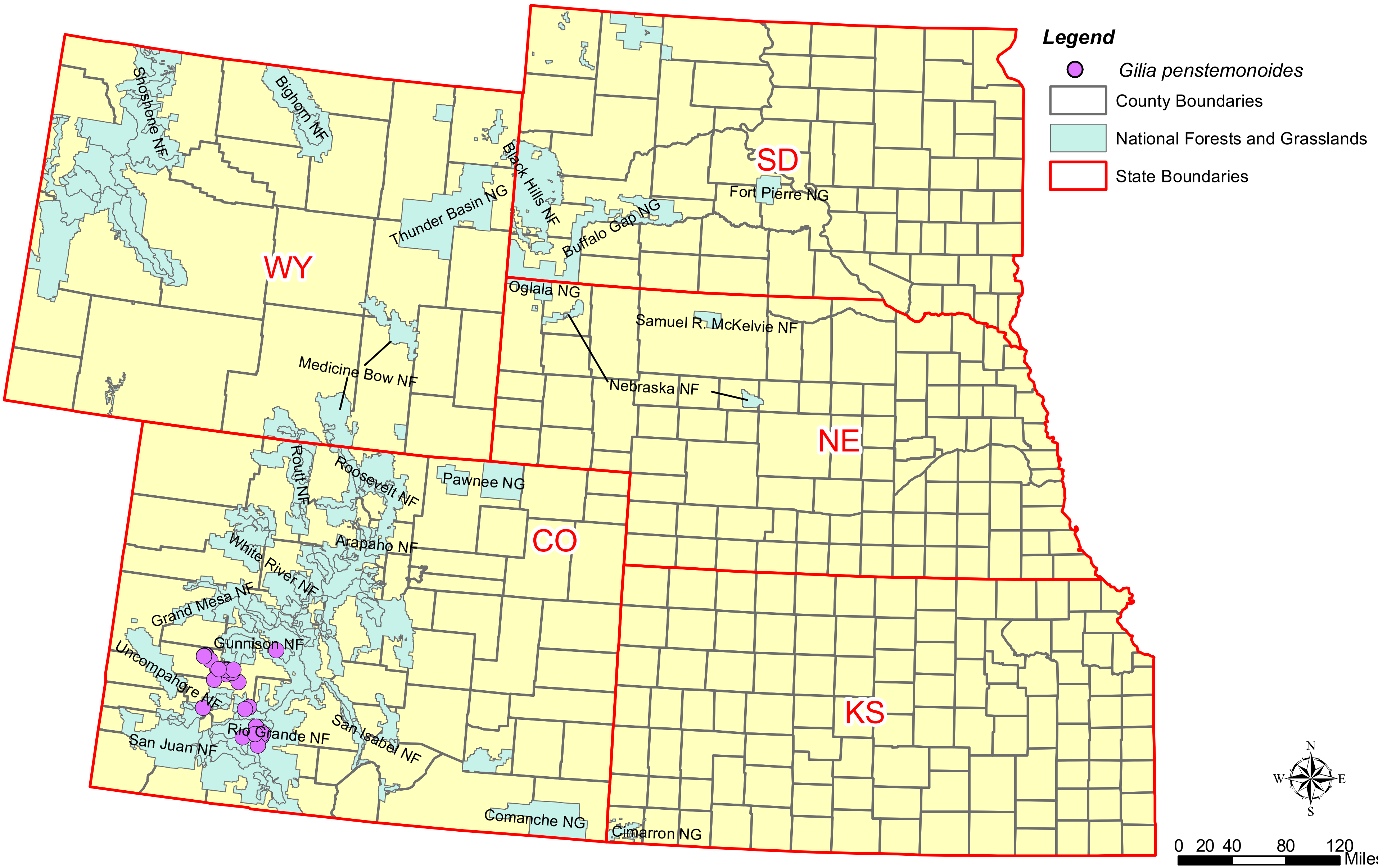

Figure 1. Map of U.S. Forest Service (USFS) Region 2 illustrating *Gilia penstemonoides* occurrences in Gunnison, Hinsdale, Mineral, Montrose, and Ourary counties, Colorado. Each occurrence may include one to several populations. Refer to document for abundance and distribution information. Source: Colorado Natural Heritage Program, Fort Collins, Colorado (2003).

Table 1. Conservation and management status of *Gilia penstemonoides* as ranked by the U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, NatureServe, and Natural Heritage Programs in Region 2 states.

Listing	Status
U.S. Forest Service Sensitive Species List[1]	Not listed
U.S. Fish and Wildlife Service Endangered Species List[2]	Not listed
U.S. Bureau of Land Management	Not listed
NatureServe Global Ranking[3]	Vulnerable (G3)
Colorado Natural Heritage Program	Vulnerable (S3)
Kansas, Nebraska, South Dakota, Wyoming Natural Heritage Programs	Not listed; Not known in states

[1]As designated by the Regional Forester; population viability is a concern due to downward trends in population numbers, density, or habitat capability.

[2]Previously designated as a Category 2 ranked species, a taxa for which current information indicates that proposing to list as endangered or threatened is possible, but there is insufficient information to support immediate rulemaking; category program was eliminated in 1996

[3]Key to rankings: G = Global rank based on rangewide status; S= State rank based on status of a species in an individual state

G1	Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction.
G2	Imperiled globally because of rarity (six to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction.
G3	Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction.
G4	Apparently secure, though it may be quite rare in parts of its range, especially at the periphery.
G5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.
S1	Critically imperiled in the state because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction.
S2	Imperiled in the state because of rarity (six to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction.
S3	Vulnerable throughout its statewide range or found locally in a restricted statewide range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction.
S4	Apparently secure, though it may be quite rare in parts of its statewide range, especially at the periphery.
S5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.

for listing as threatened or endangered because they have proven to be more widespread or abundant than previously believed and/or are not subject to any identifiable threat.) (**Table 1**; U.S. Fish and Wildlife Service 1993). The category program was eliminated by the USFWS in 1996, and those species are no longer considered candidate species (U.S. Fish and Wildlife Service 1996). Therefore, *G. penstemonoides* is not currently ranked under the Endangered Species Act.

Gilia penstemonoides was previously listed as a sensitive species by USFS Region 2 (U.S. Forest Service 1993), but it was not included on the list designated in 2003 (U.S. Forest Service 2003). Thus, this species is not currently ranked as a USFS sensitive species. *Gilia penstemonoides* occurs on Bureau of Land Management (BLM) land in western Colorado, but it is not currently listed as a BLM sensitive species (U.S. Bureau of Land Management 2000).

Heritage program ranks

Natural Heritage Programs collect and store information about the biological diversity of their respective states and maintain databases of plant species of concern. The Global Heritage Status Rank for *Gilia penstemonoides* is G3, or globally vulnerable, as a result of its limited abundance and distribution (NatureServe 2003). Because of its small distribution and rarity, *G. penstemonoides* has been ranked by the Colorado NHP as S3, or vulnerable (vulnerable to extirpation; endangered or threatened in the state) (Colorado Natural Heritage Program 2002).

This species is not known to occur in the other four states of USFS Region 2 (i.e., Kansas, Nebraska, South Dakota, or Wyoming) and is thus not currently listed or ranked in those states (Kansas Natural Heritage Inventory 2000, Nebraska Natural Heritage Program

2001, Fertig and Heidel 2002, South Dakota Natural Heritage Program 2002).

Existing Regulatory Mechanisms, Management Plans, and Conservation Practices

Known populations of *Gilia penstemonoides* occur in a variety of land ownership and management contexts in Colorado. Of the 28 occurrences of *G. penstemonoides* in USFS Region 2, 14 occurrences are on U.S. National Park Service (NPS) lands (Black Canyon of the Gunnison National Park and Curecanti National Recreation Area), eight occurrences are on USFS lands (Rio Grande, Gunnison, and Uncompahgre national forests), five occurrences are on BLM lands (Uncompahgre Field Office), and one occurrence is on private land (**Table 2**; Colorado Natural Heritage Program 2002). Of the eight occurrences on USFS lands, five occurrences are on Rio Grande National Forest, two occurrences are on Gunnison National Forest, and one occurrence is on Uncompahgre National Forest (**Table 2**). This section details regulatory mechanisms, management plans, and conservation strategies that may relate to *G. penstemonoides*.

Although *Gilia penstemonoides* has been identified as a species of special concern, there are few existing regulatory mechanisms at the federal or state level to regulate its conservation. This species was previously considered a USFWS Category 2 plant (U.S. Fish and Wildlife Service 1980), but the category program has been eliminated so there is no legal protection for this species under the ESA (U.S. Fish and Wildlife Service 1996). *Gilia penstemonoides* is not currently designated as a U.S. Forest Service Region 2 sensitive species. Although not specifically protected by sensitive species regulations, this species may still obtain some protection under various conservation strategies designed to protect plants and animals within federal lands. For example, the National Environmental Policy Act requires an assessment of impacts from every proposed federal project to the environment (U.S. Congress 1982). USFS and BLM lands are generally managed for multiple use, with an effort to prevent damage to populations of species of special concern. USFS travel management plans may protect some rare species by restricting vehicles to established roads only (U.S. Forest Service and Bureau of Land Management 2000), and wilderness areas also have restrictions on motorized travel (Office of the Secretary of the Interior 1964). BLM regulations help to minimize negative effects on special status species, especially by designating certain zones as Areas of Critical Environmental Concern, altering livestock grazing patterns, restricting off-highway vehicle use, and limiting mineral operations (U.S. Bureau of Land Management 1996). The NPS prohibits collection of any native plants without a permit (U.S. National Park Service 2002). However, the success of any of these management plans depends on adequate enforcement of the regulations.

The Colorado NHP has classified *Gilia penstemonoides* as a species of special concern due to its regional endemic status. NHP databases draw attention to species potentially requiring conservation strategies for future success. However, these ranks are not associated with specific legal constraints, such as limits to plant harvesting or to damaging habitats that support these plants. The Colorado NHP stores occurrence records for this species, which often include repeated observations of individual populations but lack detailed demographic or abundance information (Colorado Natural Heritage Program 2002). Some preliminary studies on the reproductive biology and habitat characteristics of *G. penstemonoides* were performed by Harmon and Grey (1980) and Grey (1982). There are no censuses, monitoring plans, or other demographic studies currently underway or planned for this species.

Gilia penstemonoides may be protected in part by the fact that it inhabits rugged and largely inaccessible terrain. However, existing regulations do not appear adequate to conserve *G. penstemonoides* over the long term, considering that the abundance and distribution of this species are largely unknown, specific populations may possibly be threatened by human-related or environmental/biological threats, and this species is not considered a sensitive species by the USFS.

Biology and Ecology

Classification and description

Systematics and synonymy

Gilia penstemonoides (Jones) is a member of the *Giliandra* section of the *Gilia* genus within the Gilieae tribe of the Polemoniaceae (Phlox) family of flowering plants (Anthophyta) (Grant 1959, U.S. Department of Agriculture, Natural Resources Conservation Service 2003). The family Polemoniaceae is comprised of 320 species, with 25 to 120 species within the genus *Gilia*. However, recent molecular and phylogenetic analyses by Porter (1998, 2000) have prompted reassessment of Polemoniaceae taxonomy. Porter (1998) proposed that the *Gilia* genus is polyphyletic, and he consequently

Table 2. Summary information for *Gilia penstemonoides* occurrences in Colorado (U.S. Forest Service Region 2). Includes county, occurrence identifier, date of recorded observations, estimated abundance, estimated density, estimated area, and land management context. Sources: Grey (1982), Colorado Natural Heritage Program (2002).

County	Occurrence Identifier[1]	Date of Recorded Observations	Estimated Abundance	Estimated Density	Estimated Area	Management Area/ Ownership
Gunnison	003	1961, 1980, 1982	Common (1982)	Not Available (NA)	Not Available (NA)	National Park Service (NPS) - Curecanti National Recreation Area (NRA)
	004 (G1)	1978, 1980, 1990	25 (1990)	2 plants/m^2	NA	U.S. Bureau of Land Management (BLM), NPS (?)
	005 (G6)	1980, 1981, 1990	Not Available (NA)	NA	NA	NPS - Curecanti NRA
	006	1981	NA	NA	NA	NPS - Curecanti NRA
	007 (G2)	1980, 1981	NA	2 plants/m^2	4719 m^2	BLM, private (?)
	008 (G3)	1955, 1980, 1990	Healthy and widespread (1990)	3 plants/m^2	12,558 m^2	BLM, private (?)
	009	1980, 1981	NA	NA	NA	NPS - Curecanti NRA
	010	1980, 1981	Presumed extirpated	NA	NA	NPS - Curecanti NRA
	017	1950	Presumed extirpated	NA	NA	NPS - Curecanti NRA
	023	1996	30	NA	NA	Gunnison National Forest (?); Private/Other (?)
Hinsdale	015 (G5)	1980, 1981	NA	1 plant/m^2	NA	BLM
	016	1981	NA	NA	NA	Gunnison National Forest
Mineral	019	1989, 1998	More than 50 (1998); hundreds of individuals, probably more (1998)	NA	25 acres	Rio Grande National Forest
	020	1991, 1998	Thousands in 3 suboccurrences (1998)	NA	NA	Rio Grande National Forest
	025	1998	Counted 40, estimated fewer than 100	NA	10 acres	Rio Grande National Forest
	026	1998	More than 100, possibly hundreds or more	NA	NA	Rio Grande National Forest
	027	1998	Greater than 100	NA	NA	Private
	028	1998	10	NA	1 to 10 acres	Rio Grande National Forest
Montrose	001	1890, 1998	111 (1998)	NA	NA	NPS - Curecanti NRA
	002	1961, 1988	Common (1961); rare (1961); 21 (1998)	NA	NA	NPS - Curecanti NRA
	011 (G4)	1980, 1998	3 (1998)	2 plants/m^2	NA	NPS – Black Canyon of the Gunnison National Park (BCGNP)
	012	1980, 1998	No plants (1998)	NA	NA	NPS – BCGNP
	013	1980, 1981, 1998	No plants (1998)	NA	NA	NPS - BCGNP
	014	1980, 1981	NA	NA	NA	NPS - BCGNP
	018	1937	NA	NA	NA	BLM, Cimarron State Wildlife Area (?)
	021	1980	NA	NA	NA	NPS - BCGNP
	029	1988	6	NA	NA	NPS - Curecanti NRA
Ouray	030	1988	4	NA	NA	Uncompahgre National Forest/City of Ouray - Uncompahgre Gorge Recreation Area

[1]Occurrence identifiers without parentheses are NHP element occurrence identifiers, identifiers in parentheses are Grey's 1982 study site identifiers.

moved members of the section *Giliandra* of genus *Gilia* to section *Giliandra* of the subgenus *Aliciella* of the genus *Aliciella*. Under this treatment, the genus *Aliciella* includes 21 species. In addition, Weber and Wittmann (2001a, 2001b) pointed out that the original spelling of the epithet by M.E. Jones in 1893 was "*pentstemonoides*" instead of "*penstemonoides*". Thus, the proposed name for *G. penstemonoides* under this revised treatment would be *Aliciella pentstemonoides* (Jones) J.M. Porter. Weber and Wittmann (2001a) noted that this use of *Aliciella* is controversial, although they did not provide any more details concerning the nature of the debate.

This species assessment treats this species as *Gilia penstemonoides* (Jones) as presented in the PLANTS database (U.S. Department of Agriculture, Natural Resources Conservation Service 2003), the standard reference for the USFS. This treatment under the genus *Gilia* is also used as the currently accepted taxonomic standing in the Integrated Taxonomic Information System (2002), NatureServe database (NatureServe 2002), and Colorado NHP records (Colorado Natural Heritage Program 2002). *The Catalog of the Colorado Flora: A Biodiversity Baseline* (Weber and Wittmann 2000), *Colorado Flora: Eastern Slope* (Weber and Wittmann 2001a), *Checklist of the Vascular Plants* of Colorado (Hartman and Nelson 2001), and Porter (1998) use the genus *Aliciella* for this species. Various versions of the epithet are used. Harrington (1954) uses "*G. pentstemoides*", Porter (1998) uses "*A. pentstemonoides*", Hartman and Nelson (2001) uses "*A. penstemonoides*", and U.S. Department of Agriculture, Natural Resources Conservation Service (2003) uses "*G. penstemonoides*". Johnston (2002) noted that most Rocky Mountain botanists accept *G. pentstemonoides* and some use *A. pentstemonoides*.

Common names for *Gilia penstemonoides* include Black Canyon gilia and beardtongue gilia (Colorado Natural Heritage Program 2002). Voucher specimens of this species are housed at the Colorado State University Herbarium (Fort Collins, CO), with additional specimens at the New York Botanical Garden (New York, NY), Rocky Mountain Herbarium (Laramie, WY), University of Colorado Herbarium (Boulder, CO), and University of Northern Colorado Herbarium (Greeley, CO).

Gilia penstemonoides was thought to be related to and synonymous with *G. haydenii* and *G. calcarea* (Harrington 1954, Peterson 1981), but these relationships are not supported by Porter's 1998 work with the *Aliciella* genus. Closely-related species to *G. penstemonoides* include other species in section *Giliandra* of the genus *Aliciella* (i.e., *A. pinnatifida*, *A. mcvickerae*, *A. sedifolia*, and *A. stenothyrsa*). Grey (1982) discovered plants with intermediate characteristics between *G. penstemonoides* and *G. pinnatifida* and these two species can grow in the same rock crevices and resemble each other (D. Culver personal communication 2003). Porter (1998) performed a phylogenetic analysis of this genus and concluded that these two species are distinct. Porter used a combination of morphological and molecular techniques in his analysis, but it is unclear which of these techniques was specifically used to distinguish these two species. Future study could include genetic analyses to determine the relationship between these species (Peterson 1981, D. Culver personal communication 2003).

History of species

Gilia penstemonoides was first discovered in 1890 and described three years later by botanical collector M.E. Jones (Jones 1893). J.S. Peterson (1981) completed a status report for *G. penstemonoides* on behalf of the Colorado Natural Heritage Inventory, and W. Grey (1982) conducted a study of the reproductive biology for this gilia as part of his Ph.D. dissertation. The creation of Blue Mesa Reservoir in 1978 apparently destroyed two known locations of *G. penstemonoides* (Peterson 1981, Colorado Natural Heritage Program 2002). Since the discovery of this species in the 1890s, multiple occurrences have been recorded by a variety of botanical collectors (Colorado Natural Heritage Program 2002).

Morphological characteristics

Members of the family Polemoniaceae are characterized by showy flowers with narrow tubes abruptly flaring to five flat, spreading lobes (Zomlefer 1994).

Gilia penstemonoides is an herbaceous, perennial, apparently long-lived forb. This gilia develops a caespitose growth form (grows in low branching pattern) from a much-branching root, with one to several stems 5 to 15 centimeters (cm) tall (**Figure 2**). The stems of previous seasons may remain on the plant. The basal leaves are clustered in a dense rosette about 3 cm tall. The leaves are narrow, linear to linear-lanceolate (about 5 cm long and 3 to 8 millimeters [mm] wide), and entire or irregularly pinnatisect (pinnately-lobed). The upper part of stem is sparsely glandular hairy with scattered, reduced leaves. The reduced cauline leaves are almost linear and are entire to slightly lobed. The inflorescence

(A)

Photograph by William Jennings. Reprinted with permission from the photographer.

(B)

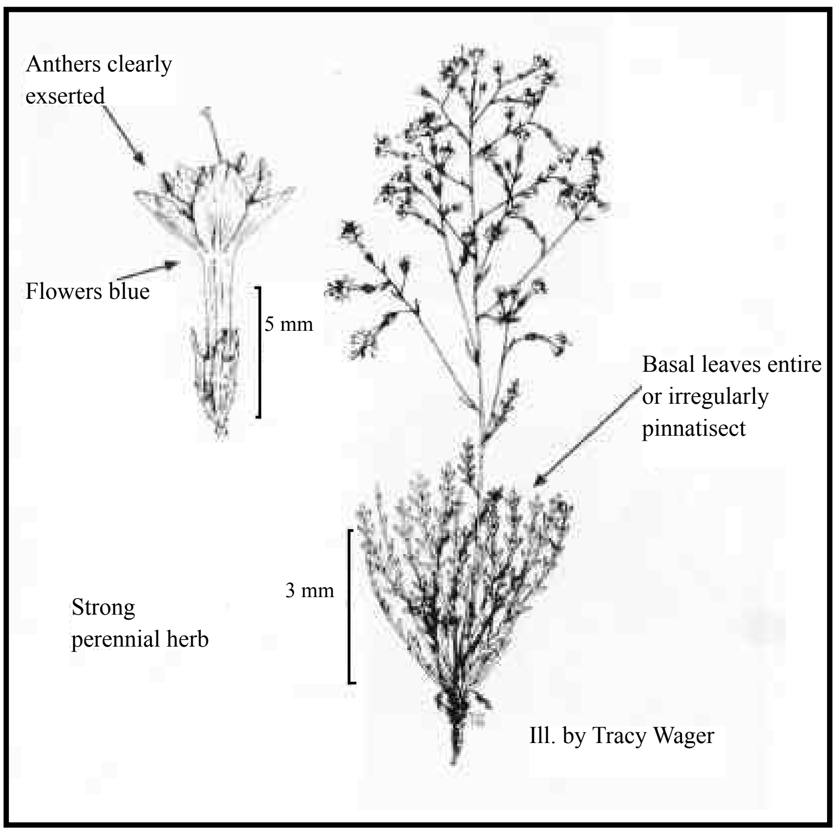

Illustration by Tracy Wager. Reprinted with permission from the artist.

Figure 2. *Gilia penstemonoides* photograph in its natural habitat (A), and illustration of the vegetative and reproductive structures (B).

is leafless and loosely branched, with lavender, purple, blue, or near-white flowers. The salverform corolla is 1 cm long, and the oval corolla lobes are shorter than the corolla tube (5 mm). The stamens and style are clearly exserted beyond the corolla tube; the stamen filaments are equal or exceeding the corolla lobes (Jones 1893, Peterson 1981, Spackman et al. 1997, Weber and Wittmann 2001a, Weber and Wittmann 2001b).

Gilia penstemonoides is not likely to be confused with other species in the same range and habitat (Spackman et al. 1997). However, the ranges of *G. penstemonoides* and *G. pinnatifida* overlap in various canyons, and some individuals have morphological characteristics intermediate between the two species (Grey 1982). Compared to *G. pinnatifida*, *G. penstemonoides* has a caespitose habit, lighter-colored lavender or bright purple flowers, longer calyx lobes, fewer internodes, and greater length of the highest anther. Compared to *G. penstemonoides*, *G. pinnatifida* has a taller habit, regularly pinnatifid leaves, deeper lavender-colored flowers, a single stem, a greater number of cauline leaf pinnae, a denser basal rosette, and a greater number of axillary flowers (Grey 1982, Porter 1998). Also, *G. pinnatifida* is a biennial or short-lived perennial that is usually found on dry, sandy, or gravelly soils in foothills or grassland habitats, often in disturbed areas (Porter 1998, Weber and Wittmann 2001a). *Gilia haydenii* has a biennial growth habit, is taller (20 to 25 cm), possesses rose-colored flowers, has longer corollas (10 to 15 mm), and is not distributed in the same geographic area as *G. penstemonoides* (Harrington 1954). *Stephanomeria* species (asters) with purple flowers can be superficially mistaken for *G. penstemonoides* (Colorado Natural Heritage Program 2002).

Technical descriptions are provided by Jones (1893), Peterson (1981), and Porter (1998). An illustration and a photo are available in Spackman et al. (1997). J.M. Porter (1998, 2000) provides a dichotomous key for the identification of Polemoniaceae species in Colorado and all *Aliciella* species.

Distribution and abundance

Members of the Gilieae tribe of the Family Polemoniaceae are mostly distributed in arid southwestern North America, but they also extend into the Rocky Mountain region, Pacific and Atlantic coasts, and to the deserts and mountains of temperate South America (Grant 1959). Many of the *Aliciella* species described by Porter (1998) are narrow endemics within the western United States, especially the Colorado Plateau area.

Distribution

Gilia penstemonoides is known only from 28 occurrences in Gunnison, Hinsdale, Mineral, Montrose, and Ouray counties in Colorado (**Figure 1**, **Table 2**; Grey 1982, O'Kane 1988, Colorado Natural Heritage Program 2002). The distribution center for this species occurs in Black Canyon of the Gunnison National Park (BCGNP) and other locations along the Gunnison River basin (Grey 1982). Since Grey's work in 1982, several additional populations have been located in the Rio Grande River basin in Mineral County, on the east side of the Continental Divide (Colorado Natural Heritage Program 2002). **Figure 1** illustrates the distribution of *G. penstemonoides* in USFS Region 2, and **Table 2** summarizes Colorado NHP occurrence records. An occurrence, as defined by the Colorado NHP (2002), is a location with one or more individuals that is separated by at least one mile or a barrier (e.g., ridge, river, road) from a neighboring population.

Of the 28 occurrences of *Gilia penstemonoides* in USFS Region 2, 14 occurrences are on NPS lands (BCGNP and Curecanti National Recreation Area), eight occurrences are on USFS lands, five occurrences are on BLM lands, and one occurrence is on private land (**Table 2**; Colorado Natural Heritage Program 2002). Of the eight USFS occurrences, five are on Rio Grande National Forest, two are on Gunnison National Forest, and one is on Uncompahgre National Forest (**Table 2**).

Within USFS Region 2, this species has not been discovered in Kansas, Nebraska, South Dakota, or Wyoming and is thus not currently listed or ranked in those states (Kansas Natural Heritage Inventory 2000, Nebraska Natural Heritage Program 2001, Fertig and Heidel 2002, South Dakota Natural Heritage Program 2002).

Abundance

In general, population sizes are difficult to determine for *Gilia penstemonoides* because of the inaccessible, extensive, and irregular nature of the cliff habitats it occupies (Grey 1982). Many of the abundance estimates were performed with the use of binoculars and from a boat at the bottom of a cliff face (i.e., cliff faces over 1000 feet tall) (Colorado Natural Heritage Program 2002). Fourteen occurrences have not been observed since 1995, and nine occurrences do not have any abundance information at all.

The abundance of *Gilia penstemonoides* ranges from three individuals to thousands of individuals (**Table 2**; Colorado Natural Heritage Program 2002). Grey (1982) did not present raw abundance data but reported population densities ranging from 1 to 3 plants per square meter at six study sites (**Table 2**, NHP occurrences #004, #005, #007, #008, #011, and #015). The frequency of this species (based on presence within sampling quadrats) at these sites ranged from 19 to 93 percent. The occurrence records also note that two historical locations of *G. penstemonoides* from 1980 were visited in 1998, but no plants were found. Two occurrences of *G. penstemonoides* were presumably extirpated through flooding with the creation of the Blue Mesa Reservoir in 1978 (Peterson 1981, Colorado Natural Heritage Program 2002).

The Colorado NHP assigns element occurrence ranks to each occurrence in order to estimate its long-term viability based on population abundance, perceived habitat quality, and potential threats (Colorado Natural Heritage Program 2002). There was insufficient information to assign a rank for six populations (E-ranked), two populations have not been observed for at least twenty years (H-ranked), and two populations are presumed extirpated (X-ranked). One occurrence was not ranked at all. The other occurrences of *G. penstemonoides* ranged from high-quality sites with robust populations to less optimal sites with fewer individuals. Four occurrences were ranked as "A" occurrences (300 or more individuals; occurrence has excellent likelihood of long-term viability; occurs in a high-quality site; various size classes are represented), two were ranked as "B" occurrences (100 or more individuals; occurrence should have good likelihood of long-term viability; various size classes are represented; occurs in an environment with 10 percent or less cover by exotic species), six were ranked as "C" occurrences (50 or more individuals; occurrence may have low probability of long-term viability; occurs in an environment with 10 to 50 percent cover by exotic species or moderate level of human disturbance), and five were ranked as "D" occurrences (less than 20 individuals in a degraded site, occurrence has a low probability of long-term viability, occurs in an environment with over 50 percent cover by exotic species or a significant level of human disturbance). Specifically, the eight ranked occurrences on USFS lands included three A-ranked occurrences, one B-ranked occurrence, two C-ranked occurrences, one D-ranked occurrence, and one E-ranked occurrence (Colorado Natural Heritage Program 2002). Notes associated with the C-ranked and D-ranked occurrences suggest that the observers could only see a small number of individuals (hence the rank), but that these small populations were in good habitat with additional inaccessible potential habitat nearby (Colorado Natural Heritage Program 2002).

Population trends

There are no data on population trends for *Gilia penstemonoides*. Although several populations were studied by Grey (1982) and several of those populations have been revisited, no multi-year population studies have been initiated to quantitatively determine population trends. As mentioned previously, occurrence records of revisited populations indicate that some populations have remained the same, some have increased, and some no longer exist (**Table 2**; Colorado Natural Heritage Program 2002). Several populations have not been verified in over 20 years, and new populations have been discovered in the last 10 years (Colorado Natural Heritage Program 2002).

Habitat characteristics

Gilia penstemonoides grows in crevices, on narrow ledges, and on rimrock of vertical or near-vertical canyon walls (Peterson 1981, Grey 1982, Spackman et al. 1997). Descriptions of *G. penstemonoides* habitat characteristics from element occurrence records are summarized in **Table 3** (Grey 1982, Colorado Natural Heritage Program 2002). The information presented in this section is based primarily on Grey's 1982 habitat analyses, which only included six study sites in Gunnison, Hinsdale, and Montrose counties.

As the Gunnison River cut through the Gunnison uplift (a crustal block with several mesas), it created low hills, mesas, slopes, and steep, narrow canyons more than 915 meters (m) (3000 feet [ft]) deep in the Black Canyon. The geologic composition includes a variety of metamorphic rocks, igneous (volcanic) outcrops, and sedimentary influences (basalt, gneiss, granite, quartz, rhyolite, schist, and shale). The main soil associations at *Gilia penstemonoides* occurrences recorded by Grey (1982) are Posant-Woodhall-Stony rock land, Shule-Youman-Passar, Parlin-Lucky-Hopkins, and Torriorthents-Rock outcrop, and the habitats within these associations are classified as Stony rock land or Rock outcrop series. Soil texture is mostly sandy with some areas having gravels, silts, or clays. Grey (1982) analyzed soil characteristics at six sites with *G. penstemonoides* and found that the carbonate (lime) levels were always low (less than one percent), the pH varied from 6.1 to 7.5, the percent organic matter ranged from 4.2 to 7.8, and the potassium and iron at these sites were higher than other Colorado soils. Grey (1982) also measured higher proportions of silts and clays in the crevices with *G. penstemonoides* compared to adjacent open soil habitats. Refer to Grey (1982) for a detailed summary of soil nutrients at each site. At some locations, *G. penstemonoides* appeared to prefer the dark-colored metamorphic rock or shales and was less abundant on the lighter-colored substrates (e.g., pegmatite). At one location, this species was growing on mixed light-colored shale and volcanics (Colorado Natural Heritage Program 2002).

The general topography of *Gilia penstemonoides* habitat tends to be irregular terrain with steep, weathering cliffs, talus sections, and ravines or gullies. The slope of this habitat is near vertical or vertical, with cliffs of 75 to 90 degrees and talus slopes of 45 to 65 degrees (Grey 1982, Colorado Natural Heritage Program 2002). The cliff walls with *G. penstemonoides* vary in aspect from south to northwest to northeast, and the plants usually receive shade for a portion of the day. Recorded elevations for this species range from 2,070 m to 3,050 m (6,800 ft to 10,000 ft) (**Table 3**; Peterson 1981, Grey 1982, Spackman et al. 1997, Weber and Wittmann 2001b, Colorado Natural Heritage Program 2002).

On rocky outcrops, *Gilia penstemonoides* can be found scattered along the cliffs from the base to upper portions of the slope, depending on the availability of cracks. *Gilia penstemonoides* requires narrow crevices with sufficient depth to promote anchorage; this species has not been observed growing in deep pockets of soil or in open areas. Grey (1982) was unable to sample large quantities of soil in the immediate root environment of this gilia, but he hypothesized that the deep, narrow cracks retained moisture. Other observers also noted that *G. penstemonoides* was growing in "damp, rocky soil" (Colorado Natural Heritage Program 2002). Gay Austin, botanist with the Grand Mesa-Uncompahgre-Gunnison National Forest (personal communication 2002), found that *G. penstemonoides* appeared to be abundant on canyon walls nearest the Gunnison River and decreased in abundance with increasing distance from the river, perhaps related to water availability or humidity.

The vegetation communities in the upper canyons of the Gunnison River basin are generally characterized by scrub oak/sagebrush/mountain brome-western wheatgrass (*Quercus gambelii*/*Artemisia* spp./*Bromus marginatus-Agropyron smithii*) communities and montane communities with lodgepole pine (*Pinus contorta*), Douglas fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*), aspen (*Populus tremuloides*), and Thurber's fescue (*Festuca thurberi*) (Grey 1982). Areas near the Blue Mesa Reservoir are characterized by a shadescale/winterfat/galleta (*Atriplex* spp./*Krascheninnikovia lanata/Hilaria jamesii*) community and pinyon/juniper/sagebrush communities (*Pinus edulis/Juniperus scopulorum/ Artemisia* spp.) with a variety of grasses (Grey 1982). However, *Gilia penstemonoides* is not really considered a part of those communities because of its affinity for sparsely-vegetated steep canyon walls. Members of the canyon wall plant community that occurred at the same sites as *G. penstemonoides*, with 10 percent frequency or greater, include *Arabis crandallii*, *Arenaria fendleri*, *Artemisia frigida*, *Artemisia ludoviciana*, *Heterotheca horrida*, *Heterotheca villosa*, *Holodiscus dumosus*, *Oryzopsis micrantha*, *Ribes cereum*, and *Selaginella densa* (Grey 1982). Peterson (1981) also recorded *Artemisia tridentata*, *Festuca arizonica*, *Geranium* spp., *Heuchera parviflora*, *Holodiscus dumosus*, *Notholaena fendleri*, *Prunus virginiana*, *Selaginella underwoodii*, and *Symphoricarpos vaccinioides* as associated species. One location featured mosses, lichens, and ferns (i.e., *Cheilanthes feei*, *Cystopteris fragilis*, *Pellaea atropurpurea*, and *Woodsia neomexicana*), and other locations featured *Amelanchier* spp., *Brickellia grandiflora*, *Cercocarpus montanus*, *Fendlera rupicola*, *Festuca arizonica*, *Poa secunda*, and *Urtica gracilis* (Colorado Natural Heritage Program 2002). Refer to Grey (1982) for a complete list of all species found with *G. penstemonoides* at his six study sites.

Reproductive biology and autecology

Life history and strategy

There have been no studies on the life history, demography, or longevity of *Gilia penstemonoides*. The hypothesized life history of this perennial plant is depicted in **Figure 3**. The rates of growth, survival, recruitment, dispersal, and longevity are unknown.

Based on vegetation strategies described by Grime (1979), *Gilia penstemonoides* could be considered a stress-tolerant, or s-selected, species because of its perennial life history and its ability to withstand harsh and unproductive conditions (Grime 1979, Barbour et al. 1987).

Reproduction

Like other species of the Polemoniaceae, *Gilia penstemonoides* produces an inflorescence of showy, conspicuous flowers, often with a strong odor to attract pollinators (Grant 1959, Zomlefer 1994). There is no reported occurrence of asexual (e.g., vegetative or

Table 3. Habitat information for *Gilia penstemonoides* occurrences in Colorado (U.S. Forest Service Region 2). Includes county, occurrence identifier, elevation range, general habitat description, associated plant species, and slope/aspect information. Sources: Grey (1982), Colorado Natural Heritage Program (2002).

County	Occurrence Identifier[1]	Elevation Range (ft)	General Habitat Description	Associated Plant Species	Slope/Aspect
Gunnison	003	Not Available (NA)	Dry rocky slope	Not Available (NA)	Steep slope
	004 (G1)	7,800 to 8,100	Cliff outcrops of metamorphic, Precambrian substrate; on vertical cliffs right beside old railroad grade; in very tight cracks with very little soil; medium to dark gray shale, unstable with patchy vegetation; very irregular terrain, mixture of steep, weathering cliffs and gulleys associated with low and high talus sections	NA	45 to 65º talus and 75 to 85º cliff faces; west, south-southeast or south aspects
	005 (G6)	7,600 to 7,700	On granite/gneiss cliffs that have been cut by the Gunnison River, prior to impoundment; large sections of solid rock with very few cracks or crevices; very little overburden, except on small, horizontal ledges; at base of extremely high cliffs and talus slopes	NA	Vertical slopes
	006	7,800	Not Available (NA)	NA	Not Available (NA)
	007 (G2)	8,400	Rocky irregular cliffs with large vertical wall sections; lower talus area, intermixed with herbaceous ground cover and some wooded canopy of Douglas fir and aspen; loose, moderately unstable talus	*Arabis* spp., *Artemisia* spp., *Holodiscus* spp., *Populus tremuloides*, *Pseudotsuga menziesii*	50 to 90º slopes; south-southwest aspect
	008 (G3)	8,000 to 8,400	Rimrock cliffs of mixed light-colored shale and volcanic rock; metamorphic rock; coarse and gravelly with small pockets of fine to medium fine soil	Lichen	85 to 90º slopes; all aspects
	009	7,200	NA	NA	NA
	010	7,080 to 7,200	NA	NA	NA
	017	7,200	Presumed extirpated by filling of Blue Mesa Reservoir	NA	NA
	023	8,400 to 8,800	Granite cliff crevices in canyon; gravelly sand substrate; no tree cover, 1% shrub cover, 5% forb cover, 1% graminoid cover, trace moss/lichen cover, 95% bare ground cover	*Polemonium brandegeei*	50 to 100% slopes; south aspect
Hinsdale	015 (G5)	9,000 to 9,200	Large, vertical cliff formations (150 to 200 ft) interspersed with ravines and large talus slopes; rock habitat with only small pockets of wind or water transported soil	NA	85º slopes; south aspects
	016	9,400	NA	NA	NA

Table 3 (cont.).

County	Occurrence Identifier[1]	Elevation Range (ft)	General Habitat Description	Associated Plant Species	Slope/Aspect
Mineral	019	8,920 to 9,840	On both sides of the creek on west and east facing slopes; trace tree cover, trace shrub cover, 2% forb cover, 1% graminoid cover, trace moss/lichen cover, 97% bare ground cover	*Brickellia grandiflora*, *Festuca arizonica*, *Urtica gracilis*	West and east aspects
	020	8,480 to 10,000	Igneous rock cliff, montane community; in small cracks, generally not on rock face; no dominant plant community; basalt substrate	NA	South aspect
	025	9,000 to 9,440	Rhyolitic cliffs overlooking highway; montane grassland; cliffs adjacent to and north of highway; *Festuca arizonica* dominant grass at base of cliff; dominant plant community is *Festuca arizonica*/ *Muhlenbergia filiculmis*; no soil, dry	*Festuca arizonica*, *Muhlenbergia filiculmis*	80 to 100% slopes; southwest aspect; open exposure
	026	8,760 to 9,400	200 to 400 foot rhyolitic cliffs with montane grasslands on the steep south-facing slopes below the cliffs; in small cracks of cliff; grasslands are dominated by *Festuca arizonica*	*Festuca arizonica*	Steep slopes; south aspect; open exposure
	027	9,000 to 9,400	Rhyolitic cliff outcrops in montane valley running north-south; sparsely vegetated cliff and rock outcrops	*Eremogone* spp., *Erigeron* spp., *Festuca arizonica*, *Picea engelmannii*, *Populus tremuloides*	80 to 100% slope; south to southwest aspect
	028	9,200 to 9,500	Montane V-shaped valley running north to south with sparsely-forested dacite (rhyolite) cliffs on the east bank; no soil, dry	*Artemisia frigida*, *Festuca arizonica*, *Pseudotsuga menziesii*, *Ribes* spp., *Ribes cereum*, *Rosa woodsii*	90% slope, west aspect, open exposure
Montrose	001	7,120 to 7,400	Crevices of vertical cliffs of dark colored metamorphic rock; less abundant on the lighter colored rock (pegmatite)	NA	Vertical slopes
	002	7,200 to 7,600	Vertical cliffs of dark colored metamorphic rock; in crevices of cliffs on damp rocky soil; dry rocky overhang	NA	Vertical slopes
	011 (G4)	7,600 to 7,761	A short vertical section in a steep ravine leading into upper section of main canyon; on vertical faces between two large boulders at top of vertical cliffs; gneiss rock with virtually no soil substrate	*Artemisia tridentata*, *Amelanchier* spp., *Fendlera rupicola*, *Heterotheca villosa*, *Quercus gambelii*, *Poa secunda*	90% slopes; all aspects
	012	7,500	Tops of vertical cliffs of a canyon	*Amelanchier* spp., *Cercocarpus montanus*, *Quercus gambelii*	Vertical slopes
	013	6,800	NA	NA	NA
	014	7,300 to 7,700	NA	NA	NA
	018	NA	NA	NA	NA
	021	7,700	On cliffs	NA	NA

Table 3 (concluded).

County	Occurrence Identifier[1]	Elevation Range (ft)	General Habitat Description	Associated Plant Species	Slope/Aspect
Montrose	029	7,040 to 7,280	In crevices and cracks in vertical granite cliffs; gilia appears to prefer the darker colored granite	NA	Vertical slopes
Ouray	030	8,800 to 8,840	In crevices of west facing face of mossy outcrop of Leadville limestone, with quartz pockets	Mosses, lichens, *Cheilanthes feei*, *Cystopteris fragilis*, *Pellaea atropurpurea*, *Woodsia neomexicana*	NA

[1]Occurrence identifiers without parentheses are NHP element occurrence identifiers, identifiers in parentheses are Grey's 1982 study site identifiers.

apomixis) reproduction by this species. The extent of asexual reproduction is unknown.

Gilia penstemonoides flowers from early June through late August and produces fruits from June to September (Peterson 1981, Grey 1982, Spackman et al. 1997). This gilia produces small, spheroidal, mucilaginous seeds about 0.5 mm in size (Grey 1982). Several observations suggest that *G. penstemonoides* is an obligate outcrosser and relies on insects to cross-pollinate flowers.

Gilia penstemonoides plants only have a few flowers in full anthesis at any one time, and there are often fruits and flowers on the plant at the same time. This staggered development tends to reduce self-pollination and encourage cross-pollination (Grey 1982). Grant and Grant (1965) artificially self-pollinated plants in an experimental garden and concluded that *G. penstemonoides* is self-incompatible. Based on a limited insect exclosure experiment, Grey (1982) found that only one mature fruit resulted from 105 enclosed flowers on four plants.

Pollinators and pollination ecology

Grant and Grant (1965) studied pollination biology of the genus *Gilia*, and they verified that cross-pollination by insects (e.g., bumblebees, beeflies) is an important reproductive factor for many *Gilia* species. *Gilia* flowers are showy, often have a strong odor, are arranged in loose, cymose inflorescences and produce nectar that collects at the base of the corolla tube (Grant and Grant 1965). Hummingbird pollination also occurs in this genus, but usually with species whose flowers are wide enough to accommodate the hummingbird bill. However, hummingbirds have been reported to extend their long tongues into flowers that are too narrow for their bill (Grant and Grant 1965).

W. Grey (1982) observed species of bumblebees (*Bombus*) and solitary bees (Hymenoptera: Megachilidae and Halictidae) visiting the flowers of *Gilia penstemonoides*. Pollinating insects (e.g., bees) come to the blue flowers of *G. penstemonoides*, cling to the exserted stamens, and collect pollen or probe for nectar in the 4 mm long corolla tube. The pollen is often collected on hairs on the venter of the bee.

Insect species visiting *Gilia pinnatifida* in Colorado included bumblebees (*Bombus*) and solitary bees (*Megachile*) (Grant and Grant 1965).

Dispersal mechanisms

Gilia penstemonoides produces small, spheroidal, mucilaginous seeds about 0.5 mm in size (Grey 1982). Grey (1982) hypothesized that these seeds are small and light enough to be wind dispersed along canyon walls, and the sticky coating may help the seeds "stick" in crevices. In addition, the seeds could possibly be dispersed by the action of rain. It is possible that raindrops could hit the ripe capsules, dislodge the seeds, assist the production of the mucilaginous coating, and carry the sticky seeds along the cliff and into crevices. Presumably, dispersal success depends on wind or water patterns, topographic heterogeneity, and availability of suitable "safe" sites (i.e., crevices). Porter (1998) suggested that the seeds of *Aliciella* are not as mucilaginous as those of other members of the Polemoniaceae.

Fertility and seed viability

Grey (1982) studied the reproductive capacity of *Gilia penstemonoides* by measuring capsule production, seeds produced per capsule, and germination success. The average number of capsules produced per plant ranged from 22.3 to 36.6 depending on the population, and the average number of seeds produced

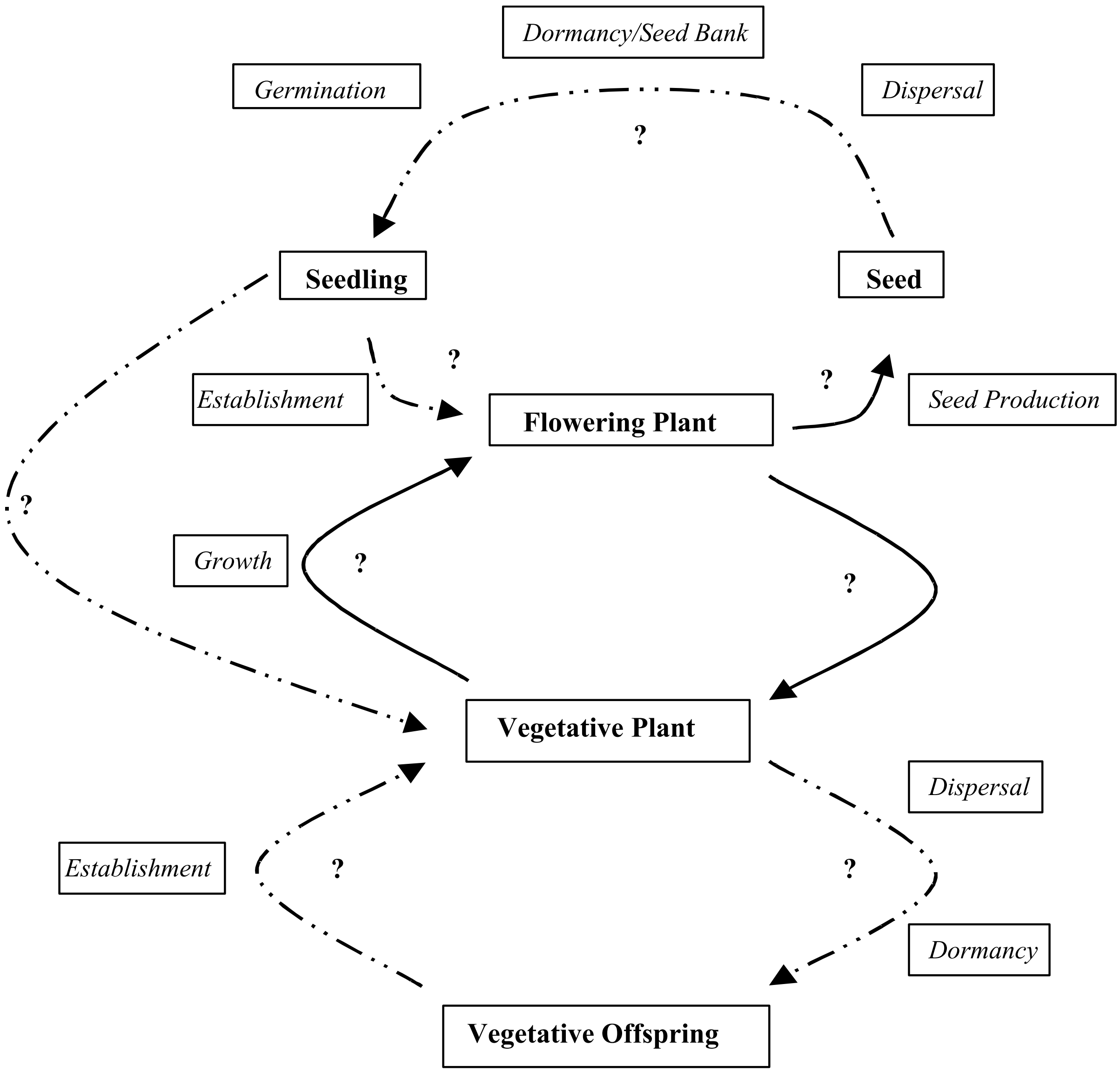

Figure 3. Schematic representation of the hypothesized life history of *Gilia penstemonoides*. There is not sufficient information about this species to create a more specific diagram. Dotted lines indicate juvenile phases of the life cycle, and solid lines indicate mature phases of the life cycle. The extent of sexual or asexual (e.g., by vegetative or apomixis) reproduction is unknown for this species. Rates of growth, dispersal, and seed production are also unknown (indicated by "?"). Figure adapted from Grime (1979).

per capsule ranged from 7 to 12.2 depending on the population (Grey 1982). Germination trials on viable seed concluded that this species has low reproductive success under experimental conditions (Grey 1982). Seventeen to 24 percent of the seeds germinated after cold stratification, and only 8 percent of non-stratified seeds germinated. After eight months of storage, a tetrazolium viability test on 50 seeds showed that 58 percent were nonviable, 34 percent were weakly viable, and 8 percent were strongly viable. Grey (1982) estimated that *G. penstemonoides* has a reproductive capability of about 50 percent as a result of low seed production and poor germination success.

Cryptic phases

No information regarding cryptic phases of *Gilia penstemonoides* is available. Seed dormancy can be an important adaptation by which plant populations exploit favorable conditions in a harsh environment (Kaye 1997). The extent of seed dormancy is not known, nor do we know if a persistent seed bank exists in the soil.

Grey (1982) could not perform a quantitative soil seed bank analysis for *G. penstemonoides* because the seeds became mucilaginous when wet, which hindered the separation of seeds from the soil. A laboratory test of long-term viability suggested that *G. penstemonoides* seeds would have low germination success after eight months (Grey 1982).

Phenotypic plasticity

Phenotypic plasticity is demonstrated when members of a species vary in height, leaf size, flowering (or spore-producing) time, or other attributes with changes in light intensity, latitude, elevation, or other site characteristics. Some white-flowered variants of *Gilia penstemonoides* exist, but these are not common (Grey 1982, Colorado Natural Heritage Program 2002). The plants discovered by Grey (1982) appeared to have intermediate characteristics between *G. penstemonoides* and *G. pinnatifida*. These could be the result of hybridization or phenotypic plasticity by *G. penstemonoides*.

Mycorrhizal relationships

The existence of mycorrhizal relationships with *Gilia penstemonoides* has not been studied.

Hybridization

As noted, hybridization between *Gilia penstemonoides* and a closely related species, *G. pinnatifida*, is suspected but not confirmed. Grey (1982) presented morphological data and statistical analyses describing individuals with intermediate characteristics at two sites; he noted five sites (**Table 2**, NHP occurrences #001, #004, #007, #015, and #030) with possible intermediate individuals. He suggested that these intermediate specimens were a source of taxonomic confusion and could be considered putative hybrids or ecotypes of either species until further study. Porter (1998) performed a phylogenetic analysis of this genus and concluded that these two species are distinct. Porter used a combination of morphological and molecular techniques in his analyses, but it is unclear which of these techniques was specifically used to distinguish these two species. Further studies through cross-breeding tests, chromosome analysis, and chromatography would help verify the presence of hybridization and relationship between these species (Grey 1982, D. Culver personal communication 2003). Hybridization, whether natural or anthropogenic, can lead to rare species extinction when a more abundant congener genetically swamps the rare species, when hybrid offspring outcompete the rare parent species, or when the production of hybrid seed reduces reproductive success of the rare species (Day 1965, Grey 1982, Glenne 2003). Day (1965) discovered that hybrid *Gilia* individuals had reduced seed size and production. Because *G. penstemonoides* does come in contact with the more common *G. pinnatifida* at some locations, the occurrence of hybridization or existence of pre-zygotic or post-zygotic isolating mechanisms is an important area of research for this species.

Demography

Life history characteristics

There is little information regarding population parameters or demographic features of *Gilia penstemonoides*, such as metapopulation dynamics, life span, recruitment, and survival. There have been some observations of percentage fruiting and evidence of young age classes by Peterson (1981), Grey (1982), and botanists contributing to NHP records (Colorado Natural Heritage Program 2002), but there have not been any multi-year demographic studies. Botanists noted if they saw young, non-flowering plants that might be juvenile plants and would potentially indicate successful reproduction (Peterson 1981, Grey 1982, Colorado Natural Heritage Program 2002). Observations of *G. penstemonoides* populations indicate that some populations have evidence of reproductive activity (i.e., young non-flowering individuals) and other populations do not seem to have new individuals (Peterson 1981, Grey 1982, Colorado Natural Heritage Program 2002). For example, Peterson (1981) recorded that populations exhibited various age classes from non-flowering rosettes to large, flowering individuals. Of eight age class observations, three observations noted that there were no signs or minimal evidence of young plants, three observations noted that small, non-flowering plants were relatively uncommon or occasional, and two observations indicated that there were several age classes and that reproduction seemed successful. In addition, Grey (1982) and Colorado NHP (2002) records indicate that many populations demonstrated 80 to 100 percent flowering and evidence of fruiting, whereas several populations had minimal evidence of fruiting.

Life cycle diagram and demographic matrix. Demographic parameters, such as recruitment and survival rates, have not been investigated for *Gilia penstemonoides*, and so there are no definitive data regarding the vital rates that contribute to species fitness. Although stage-based models based on population matrices and transition probabilities can be used to assess population viability (Caswell 2001), adequate quantitative demographic data are needed for input into the model. A life cycle diagram is a series of nodes that represent the different life stages connected by various arrows that represent the vital rates (i.e., survival rate, fecundity). The specific events in the life cycle or longevity of *G. penstemonoides* are unknown. For *G. penstemonoides*, the stages that could potentially be incorporated into a demographic matrix include seed, seedling, vegetative individuals (rosettes), and reproductive (mature) adults (**Figure 3**).

Population viability analysis. No demographic monitoring has been initiated for *Gilia penstemonoides*. To initiate a population viability analysis for *G. penstemonoides*, the rates of germination, fecundity, survival, and other important parameters require additional study.

Spatial characteristics

Overall, populations of *Gilia penstemonoides* are scattered and variable in size and density (Grey 1982, Johnston 2002). Estimates of the area covered by an existing population range from 1 to 25 acres (**Table 2**; Grey 1982, Colorado Natural Heritage Program). Grey (1982) noted that estimating population sizes or available habitat was difficult due to the high habitat heterogeneity and complex cliff topography. Further, estimating the availability of suitable habitat is almost impossible due to the large area of the canyon walls and difficulty in accessing it (Grey 1982). Further studies of *G. penstemonoides* in these areas will require technical rock-climbing (rappelling) techniques and modified sample plots (Grey 1982).

The distribution of *Gilia penstemonoides* within its habitat is largely affected by the microtopography of the cliff walls. For example, the populations of this species often run vertically, like the crack systems on cliffs (Peterson 1981). The amount and orientation of suitable substrate dictates the density of *G. penstemonoides*. There were high densities and frequencies of *G. penstemonoides* in areas where weathering had created a larger number of crevices (Grey 1982). The density of *G. penstemonoides* was reported as 1 to 3 individuals per square meter, and the frequency of this species ranged from 19 to 93 percent (**Table 2**). The highly variable densities and frequencies probably result from the variable distribution of suitable crevices and ledges (Grey 1982, Colorado Natural Heritage Program 2002). In addition, it is possible that water availability, such as humidity and water stress, may differ along the length of a cliff from top to bottom. For example, *G. penstemonoides* appeared to be more abundant on canyon walls nearest the Gunnison River and decreased in abundance with increasing distance from the river (G. Austin personal communication 2002). Also, it is possible that water may be more available at lower portions of a cliff compared to upper portions as a result of a greater opportunity for run-off or condensed or intercepted moisture to collect in lower areas. The amount of available water in various microhabitats and the effect of water availability on the growth or mortality of *G. penstemonoides* have not been studied.

The extent to which gene flow occurs between populations is unknown. The spatial distribution of *Gilia penstemonoides* in scattered populations amid irregular topography may restrict gene flow and potentially reduce the extent of sexual reproduction in this species (Grey 1982). Robin Bingham, a professor at Western State College, observed a population of *G. penstemonoides* in Taylor River Canyon (Gunnison National Forest and private lands). She hypothesized that adequate gene flow could probably occur within that population because individuals were scattered along the entire length of the area, not only in disjunct groups. However, there is probably little gene flow between this population and additional populations located in other canyons of the Gunnison River basin (R. Bingham personal communication 2002).

In general, characteristics that could influence the spatial distribution of rare species may include habitat availability, seed dispersal, presence of other vegetation, landscape and microsite heterogeneity, and disturbance or weathering patterns.

Genetic characteristics and concerns

The genetic status of *Gilia penstemonoides*, including issues related to hybridization and genetic variability, is largely unknown. The diploid chromosome number for *G. penstemonoides* is 16, which is unique to only five *Gilia* species, including *G. pinnatifida* (Grant 1959, Grey 1982). Further studies through cross-breeding tests, chromosome analysis, and chromatography would help to verify the presence of possible hybridization between *G. penstemonoides* and *G. pinnatifida* (Grey 1982, D. Culver personal communication 2003).

Understanding genetic issues, such as the taxonomic status of *Gilia penstemonoides* and *G. pinnatifida*, and the extent of gene flow, inbreeding, and genetic isolation, would have important implications for our understanding of demography, ecology, and management implications for this species.

Ecological influences on survival and reproduction

No specific information exists concerning the influence of environmental conditions or ecological factors on reproduction in *Gilia penstemonoides*. However, environmental fluctuations, such as available moisture, length of growing season, and temperature fluctuations could potentially affect growth, seed maturation, germination, and seedling survival of this species (Grey 1982). For example, decreased spring snowmelt could possibly reduce the new growth of *G. penstemonoides* (Grey 1982). A prolonged drought could possibly cause water stress to existing individuals as well as possibly prevent establishment of new seedlings. Changes to existing climatic and precipitation patterns could perhaps result from global environmental changes. As a result of its dependence on pollinating insects, low pollinator availability could negatively affect the reproductive success of this plant. Population growth or establishment for this species could possibly also be limited by competition with other species, lack of suitable germination sites, barriers to dispersal, or limited gene flow between populations.

Community ecology

Herbivores and relationship to habitat

No evidence of herbivory has been reported for *Gilia penstemonoides*, and the extent of herbivory by insects or small mammals is unknown. One of the authors of this assessment did not see any signs of damage or herbivory on plants that he had observed at several locations.

Gilia penstemonoides is generally not accessible to ungulates or livestock (Peterson 1981). D. Erhard (personal communication 2002) believed that grazing could not affect populations of *G. penstemonoides* on cliffs, and livestock and large wildlife also would avoid the tops of the cliffs because they are so dry and hard to reach. Individuals of this species found at cliff bases could potentially be more at risk than individuals on cliff faces. However, livestock generally avoid areas with talus substrate and minimal forage, especially in canyons with steep gradient streams (B. Johnston personal communication 2003). In some areas, such as Taylor River Canyon (Gunnison National Forest and private land), livestock move through the riparian area only for 3 to 10 days in the summer and fall en route between pastures, and the impact of livestock on riparian areas is thus minimalized (G. Austin personal communication 2002). She also noted that ranchers move the cattle along the road quickly and avoid letting livestock "camp" in any area. The possible indirect impacts of livestock activities, such as importation of non-native plant seeds, have not been studied.

Competitors and relationship to habitat

The interactions of *Gilia penstemonoides* within the plant community are not well known. Competition for suitable sites may occur between *G. penstemonoides* and other plant species found in these rock habitats. *Gilia penstemonoides* appears to be mainly restricted to rock crevices, whereas other species can maintain populations on both the steep terrain and adjacent talus and gravel slope habitats. Grey (1982) sampled plant species within and adjacent to *G. penstemonoides* populations at his six study sites to estimate how many of the associated species at the study sites may compete with *G. penstemonoides*. He found that 26 percent of the species inhabit only rock habitat similar to that of *G. penstemonoides*, 24 percent of the plants inhabit both rock and adjacent habitats, and 50 percent of the species were only found in the talus or gravel slope habitat adjacent to *G. penstemonoides* populations (Grey 1982). Thus, 50 percent of the plant species in these areas could potentially compete with *G. penstemonoides* for suitable rock crevice habitat. Commonly occurring species like *Heterotheca villosa*, *Arenaria fendleri*, and *Artemisia frigida* could compete for substrates with *G. penstemonoides* as well as occupy nearby substrate that is not suitable for *G. penstemonoides*. One of the authors of this assessment did not observe any other vascular plant species sharing the cracks inhabited by *G. penstemonoides*.

There are no reports of non-native invasive species specifically affecting *Gilia penstemonoides* (Colorado Natural Heritage Program 2002). Grey (1982) assessed associated plant species at six *G. penstemonoides* study sites on non-USFS lands. He listed three non-native species (*Bromus inermis* [smooth brome], *Bromus tectorum* [cheatgrass], and *Poa compressa* [Canada bluegrass]) found at three of the sites. Of those species, only *Bromus tectorum* was within *G. penstemonoides* population areas at one site; the other two species were only found adjacent to population areas. The extent of these species currently at those sites is not known. Two of those populations were visited since 1982, but significant impacts from non-native plants were not noted.

Although the cliff habitats where *Gilia penstemonoides* grows are unlikely terrain for non-native plant invasion, there is evidence of invasive plants within other cliff habitats. A study of limestone escarpments in Ontario, Canada found that up to 81 percent of all the vegetation found on cliff edges, cliff faces, and cliff bases was non-native (McMillan and Larson 2002). The researchers hypothesized that rock climbers inadvertently brought non-native, invasive plants to the area through seed transport. There is rock climbing activity in some areas with *G. penstemonoides*, and this could potentially lead to introduction of invasive plant species. Invasive plant seed could also move to these habitats via water or wind dispersal from clifftop populations or via animal dispersal (droppings from cliff-nesting birds).

Parasites and disease

There is no information concerning the role of parasites or diseases in the life cycle of *Gilia penstemonoides*. Several element occurrence records indicated that there was no evidence of parasites or disease on the *G. penstemonoides* individuals (Colorado Natural Heritage Program 2002).

Symbiotic interactions

Insect pollination of flowering plants is an example of an important symbiotic interaction. Plants lure insects to a pollen or nectar reward, and the insects carry pollen to other flowers, thus, facilitating cross-fertilization. *Gilia penstemonoides* relies on bees and other pollinators for successful sexual reproduction.

CONSERVATION

Threats

Threats to the long-term persistence of *Gilia penstemonoides* in USFS Region 2 are mostly unknown because of the lack of species understanding and research. The information on threats to *G. penstemonoides* is primarily based on a series of status reports from the 1980s (Harmon and Grey 1980, Peterson et al. 1981, Grey 1982), personal communications with land managers (G. Austin personal communication 2002, D. Erhard personal communication 2002, Johnston personal communication 2003), and element occurrence records (Colorado Natural Heritage Program 2002).

Of the 28 occurrences of *Gilia penstemonoides* in USFS Region 2, eight are on National Forest System lands in Colorado (**Table 2**). All of the occurrences on USFS lands are in areas managed for multiple uses (i.e., not in designated wilderness, research natural, or special interest areas). Because this species is not on the USFS or BLM sensitive species lists, it does not gain any protection from policies directed towards sensitive species. The remaining 20 populations occur on NPS, BLM, state, city, or private lands and any management or protection of these populations is not known. Grey (1982) noted that habitat is well-protected in the BCGNP and that smaller canyons on USFS and BLM lands generally have a higher frequency of human activity.

All populations of *Gilia penstemonoides* could be threatened by a variety of human-related activities (e.g., recreation) or environmental changes (e.g., global climate changes, invasive species introduction). The specific threats and the intensity of those threats will vary among populations. Estimating the number of populations potentially threatened by certain activities (e.g., trail or road activity) is associated with considerable uncertainty because the spatial juxtaposition of *G. penstemonoides* individuals with potential disturbances is unknown. For example, a population may be "near a road" and could subsequently suffer intense impacts from direct trampling, road dust, associated erosion and deposition. Alternatively, it could suffer minimal effects if the road is not heavily traveled or if the population is some distance from the road or above the road on a cliff. Direct impacts could either damage the existing individuals or reduce reproductive success, available habitat, establishment of new populations, or other factors important for the long-term persistence of the species.

Human-related activities, such as motorized and non-motorized recreation, trail or road construction and maintenance, reservoir creation or expansion, or invasive species introduction could have direct or indirect negative impacts on *Gilia penstemonoides* populations or habitat. Those populations closest to roads, trails, campgrounds, viewpoints, fishing and rock climbing areas, and reservoirs are likely at the most risk. Overutilization of *G. penstemonoides* for educational, horticultural, or scientific purposes is unknown, but any increased demand for this species could be a future threat. One element occurrence record noted that the population with three plants may have been impacted by tourist collecting or it may never have had many plants (Colorado Natural Heritage Program 2002). One of the authors of this assessment believes that the flowers of *G. penstemonoides* are too small to be targeted for a bouquet by tourists and there are no plants directly on the side of the visitor trail at that location.

Most populations of *Gilia penstemonoides* appear to be naturally protected from direct human impacts by their occupation in highly inaccessible cliff face habitats. Recreational activities near cliff bases, such as fishing, pack trail use, hiking trail use, or rock climbing could directly or indirectly affect individuals, particularly individuals located in talus areas at cliff bases. Possible impacts to this species could also include tourist viewing at clifftop viewpoint areas. Thirteen occurrences of *G. penstemonoides* are possibly near a road, trail, viewpoint, dam, fishing area, campground, or rock climbing area. Of these 13 occurrences, seven occur on USFS lands. Rock climbing occurs in certain locations (Taylor River Canyon in Gunnison National Forest, BCGNP), and *G. penstemonoides* is found both along climber's access trails and along the rock climbing routes (R. Bingham personal communication 2002, Colorado Natural Heritage Program 2002). The element occurrence record for that Gunnison National Forest occurrence stated, "These cliffs are often used by recreational rock-climbers. Some plants are probably being trampled." (Colorado Natural Heritage Program 2002). D. Erhard (personal communication 2002), ecologist with the Rio Grande National Forest, has never seen climbing activity on cliff habitats with *G. penstemonoides* within that forest. Ice climbing occurs in parts of the Uncompahgre Gorge Recreation Area (partly on Uncompahgre National Forest lands) during the winter, but the extent of rock climbing in areas with *G. penstemonoides* is not known. Six occurrences of *G. penstemonoides* on National Forest System lands are near streamside trails, and hiking, use of pack animals, or fishing access on those trails could possibly impact *G. penstemonoides* individuals at the base of the cliffs (Grey 1982, G. Austin personal communication 2002, Colorado Natural Heritage Program 2002). However, at least four of the element occurrence records from National Forest System lands noted that the impact of road or trail use on individuals was thought to be minimal, and described *G. penstemonoides* habitat as undisturbed, in pristine condition, or naturally well-protected. One population on Gunnison National Forest is approximately 0.2 miles from a campground, but the effect of that campground on the population is unknown. Tourist access areas adjacent to *G. penstemonoides* populations in BCGNP may cause some impact to the land, but tourists generally do not access the actual rock habitat with this gilia (Peterson 1981, Colorado Natural Heritage Program 2002). Possible indirect impacts from human activities, such as non-native species invasion and dust creation, have not been studied. Grey (1982) noted that even in areas with nearby human activities, extensive areas of potential habitat exist above the lower cliff areas or below the overlook areas. *Gilia penstemonoides* is presumably found on these cliff areas that are precipitous and, in most cases, unreachable by humans (Grey 1982, Colorado Natural Heritage Program 2002).

Other human-related impacts to *Gilia penstemonoides* could include reservoir creation or expansion, mining activities, or road maintenance or construction that would cause the habitat areas to be flooded or blasted. Direct habitat destruction by structure construction or vehicle use is generally not a risk for populations on tall, steep canyon walls. *Gilia penstemonoides* populations in smaller tributary canyons, on smaller rock outcrops, or at the base of cliffs could be more susceptible to human activity (Grey 1982). Two populations of this gilia were flooded with the creation of the Blue Mesa Reservoir (Grey 1982, Colorado Natural Heritage Program 2002). The possibility of additional dam creation and canyon flooding or reservoir expansion in the Gunnison River basin is thought to be minimal but still possible. Populations near the reservoir water line could be affected by changes in water levels. One extensive and dense population of *G. penstemonoides* in the Rio Grande National Forest occurs partly along a roadside on mine tailings from the early 1900s and appears healthy (Colorado Natural Heritage Program 2002). It is unknown if those tailings were comprised of unprocessed waste rock, processed ore, or a combination of the two. While historical mining occurred in this habitat, the extent of any current resource development or use of that road is not known. Two other populations on non-USFS lands occur above or along a private road or railway grade, but there appears to minimal impact to the *G. penstemonoides* populations at those locations (Grey 1982, Colorado Natural Heritage Program 2002).

Gilia penstemonoides is likely not threatened by typical USFS land management techniques, such as livestock grazing, timber harvest, thinning, or prescribed fire. As discussed, livestock grazing is thought to be a minimal threat due to the largely inaccessible cliffs and sparsely-vegetated habitats (G. Austin personal communication 2002, D. Erhard personal communication 2002, B. Johnston personal communication 2003). The possible indirect impacts of livestock activities, such as importation of non-native plant seeds, have not been studied. In addition, the indirect impacts of any pesticide use on pollinator populations and the reproductive success of *G. penstemonoides* are not known.

Environmental or biological threats to populations or habitats of *Gilia penstemonoides* could include non-native species introductions, herbivory, inadequate pollination, genetic isolation, hybridization, global climate change, or other changes to the natural disturbance regime that would affect precipitation or weathering patterns. Existing *G. penstemonoides* individuals could be affected by intense weathering, erosion, or rockfalls. As discussed previously, this species is unlikely to be impacted by wildfires or blowdowns. The extent and effects of any herbivory on the long-term persistence of *G. penstemonoides* are unknown. Non-native plant species (i.e., *Bromus inermis*, *Bromus tectorum*, and *Poa compressa*) were found at three of the non-USFS sites with *G. penstemonoides*, and they possess the potential to compete with this species for resources. Any increase in non-native species invasion is a future risk for competition with *G. penstemonoides*, especially for populations near trails, roads, and other disturbed areas.

Changes to existing climatic and precipitation patterns, perhaps as a result of global environmental change, could also impact *Gilia penstemonoides*. For example, average temperatures have increased 4.1 ºF, and precipitation has decreased up to 20 percent in some areas of Colorado (U.S. Environmental Protection Agency 1997). Climate change and other potential changes to a suite of environmental variables could affect plant community composition by altering establishment, growth, reproduction, and mortality of plants. For example, a prolonged drought could cause water stress to existing *G. penstemonoides* individuals as well as possibly prevent establishment of new seedlings. It is also possible that changes to climatic factors could impact weathering of the cliff habitats with this species, thus impacting current or future habitat availability. The extent and effects of atmospheric pollution (e.g., deposition of nitrogen oxides) in this region are unknown.

If *Gilia penstemonoides* largely depends on outcrossing for maximum seed set, then any reductions in pollinator efficiency could reduce reproductive success. For example, environmental stochasticity could cause fluctuations in pollinator activity and behavior. In addition, the amounts of gene flow, genetic variability, and inbreeding depression are unknown for *G. penstemonoides*. It is possible that this species' spatial distribution, in scattered populations amid irregular topography, may restrict gene flow and potentially reduce the extent of sexual reproduction (Grey 1982). The implications on long-term persistence of this species have not been studied. The extent of hybridization with *G. pinnatifida* has not been assessed, but it is a possible threat, based on conservation issues raised for other rare species (e.g., Day 1965, Glenne 2003). Further studies through cross-breeding tests, chromosome analyses and chromatography would help verify the presence of possible hybridization between *G. penstemonoides* and *G. pinnatifida* (Grey 1982, D. Culver personal communication 2003).

Threats to the long-term persistence of *Gilia penstemonoides* populations or habitats likely differ for each of the 28 occurrences. The most significant threats to the eight occurrences of *G. penstemonoides* on National Forest System lands probably include non-native plant invasions, recreational activities (e.g., rock climbing), global environmental changes, and hybridization. Populations at cliff bases or cliff tops near roads, trails, rock-climbing areas, campgrounds, or reservoirs are likely at higher risk from the detrimental effects of land use activities and non-native plant invasion.

Conservation Status of the Species in USFS Region 2

Gilia penstemonoides is a species of special concern because of its endemic distribution, small number of documented occurrences, and possible human-related and environmental threats to its persistence. Much information is lacking concerning the full abundance, distribution, and biology of *G. penstemonoides*. Eight of the 28 known populations of *G. penstemonoides* occur on National Forest System lands in Region 2 (**Figure 1**, **Table 2**). The conservation of these populations is important to the global conservation status of this species and is the main focus of the discussion presented in this document.

The viability of *Gilia penstemonoides* within USFS Region 2 is difficult to ascertain because its full distribution and abundance are unknown, demographic parameters have not been studied, and the effects of human activities (i.e., rock-climbing, trail use) have not been studied. Thirteen of the 28 populations have not been observed within the last 10 years, but all eight of the USFS populations have been observed since 1998 (**Table 2**). Non-native plant invasions, recreational activities (e.g., rock climbing), global environmental changes, and hybridization potentially threaten *G. penstemonoides* on USFS lands. Although the number of documented *G. penstemonoides* populations throughout the range is low, populations appear to inhabit largely inaccessible terrain. The long-term viability of *G. penstemonoides* within USFS Region 2 is unknown, but the rangewide vulnerability of this species to imminent destruction appears to be low. Specific populations may be at more risk than others. Based on the available information, it is difficult to assess if this species is persisting under current natural disturbance regimes and with current levels of recreation activities. It is also difficult to predict the ability of *G. penstemonoides* to tolerate environmental stochasticity in the future (e.g., global environmental changes, invasive species) and any future management changes (e.g., natural resource development).

Population declines

Based on available data, it would be difficult to conclude that the distribution or abundance of *Gilia penstemonoides* is declining or expanding throughout its range. Although a few populations have been re-observed several times since their initial identification, the reports usually do not include detailed abundance or demographic information. The sizes of the populations range from three to thousands of individuals (Colorado Natural Heritage Program 2002). Three populations on USFS lands are ranked as excellent likelihood for long-term viability, one is ranked as good likelihood for long-term viability, two are ranked with low probability for long-term viability, one is ranked with low probability of low survival, and one lacked sufficient evidence for ranking (Colorado Natural Heritage Program 2002). However, notes associated with the lower viability occurrences suggested that the observers could only see a small number of individuals (hence the rank), but that these small populations were in good habitat with additional inaccessible potential habitat nearby (Colorado Natural Heritage Program 2002). Only four A-ranked occurrences are known for this species, and three of those populations are on USFS lands.

There have been new discoveries of *Gilia penstemonoides* since 1998, and researchers believe that there probably are more occurrences yet to be found (G. Austin personal communication 2002, R. Bingham personal communication 2002, Colorado Natural Heritage Program 2002, D. Erhard personal communication 2002, Johnston 2002). Johnston (2002) suggested that we know about less than half of the populations. On the other hand, observers revisited at least four historical locations for *G. penstemonoides* and failed to find any plants (Colorado Natural Heritage Program 2002), and Grey (1982) surveyed suitable habitat with similar habitat characteristics that did not have any *G. penstemonoides* individuals. In addition, botanists have noted a paucity of young juvenile plants at some locations, indicating possible poor reproductive success at those locations. However, all five of the Rio Grande National Forest populations are thought to be healthy (Colorado Natural Heritage Program 2002). The rate at which this species disperses and colonizes new locations is unknown, because we know little of its dispersal and establishment capabilities. Not enough data are available to conclude if populations of this species are increasing, decreasing, or remaining stable. At best, we can conclude that there are several established populations in existence, the long-term viability may differ among populations, and there are potentially more populations to be discovered.

Habitat variation and risk

Gilia penstemonoides is a specialist of vertical or near-vertical rock outcrops and canyon walls of granite, gneiss, schist, rhyolite, or volcanic parent materials. Actual availability of habitat with appropriate microsite conditions (e.g., moisture availability, suitable crevices) is difficult to quantify because the cliff faces are extensive and inaccessible. Many botanists have suggested that much potential habitat exists above or below observed individuals, but the presence of *G. penstemonoides* in those areas has yet to be determined. It is possible that, despite a large amount of total cliff face habitat, *G. penstemonoides* may only inhabit the cliff base or rimrock areas where it has been observed.

Overall, most of these cliff habitats are generally resilient to human activities because they are inaccessible and rugged (Johnston 2002). As a result, they are not imminently threatened by land management activities such as livestock grazing, structure construction, or off-road recreational use. *Gilia penstemonoides* populations in smaller tributary canyons, on smaller rock outcrops, or at the base of cliffs could be more susceptible to human activity (Grey 1982). Specific populations in these habitats could be at risk for damage from rock climbing, trampling on cliffside trails, road creation involving rock blasting, mining activities, or reservoir creation or expansion. Rock climbing and trail and road activities are probably more of a persistent concern on USFS lands than reservoir creation or rock blasting.

Other limiting factors or risks within *Gilia penstemonoides* habitat could include competition from other vegetation (e.g., non-native invasive species), lack of suitable germination sites, fluctuations in environmental conditions (e.g., drought), herbivory, possible hybridization with co-occurring *Gilia* species, inadequate pollinator habitat, barriers to gene flow, or natural weathering patterns (e.g., erosion, deposition, rockfall). Fluctuations in natural disturbance processes could positively or negatively affect existing populations or creation of habitat. For example, erosional events could damage existing individuals or aid in dispersal and creation of habitat for establishment of new populations.

Individuals and populations of *G. penstemonoides* tend to be scattered throughout apparently suitable habitat; the spatial distribution of this species is possibly tied to the availability of suitable crack habitat and water availability. The availability and quality of suitable habitat most likely ranges from area to area, depending on heterogeneity in topography, substrate, disturbance factors, and competition with other species. Marginal habitats for this species may include areas where competition from other species is intense, water stress or erosion is a detriment, or where recreational activity damages plants. Three non-native, invasive species have been identified in the vicinity of *G. penstemonoides* populations, although only one species has been recorded within actual population areas. The steep cliff habitats of *G. penstemonoides* may not be suitable for the establishment and spread of any invasive plants or it may just be a matter of time for an invasive species to exploit those habitats. Thus, competition from invasive species is not a current concern for *G. penstemonoides* or its habitats, but invasive species are being introduced all the time and they may be a future threat. Other commonly occurring native species (e.g., *Heterotheca villosa*, *Arenaria fendleri*, and *Artemisia frigida*) have also been identified as potentially competing with *G. penstemonoides* for crevice habitat while also been able to exploit adjacent open soil habitat. Possible hybridization between *G. penstemonoides* and co-occurring *Gilia* species at five sites has been identified with plants exhibiting intermediate characteristics, but the genetic evidence for hybridization, rangewide extent of hybridization, and possible risk to long-term viability of *G. penstemonoides* has not been studied.

Life history and ecology

The lack of information regarding the basic biology, colonizing ability, vegetative and sexual reproductive potentials, and genetic variability of *Gilia penstemonoides* makes it difficult to pinpoint the biological or ecological characteristics important for long-term persistence of this species.

The fact that *Gilia penstemonoides* grows in steep cliff habitats may help to buffer the species from the consequences of land management activities at most locations. Populations at cliff base or cliff top areas are likely more susceptible to human-related impacts. Persistence of a *G. penstemonoides* individual may depend on its ability to anchor itself in rock crevices, access moisture, and store resources. An existing plant could be negatively impacted by disruption to the rock surface or crack that jeopardizes its "hold" on the cliff face. The apparent stress-tolerating abilities of this species may possibly aid it to persist during short-term environmental fluctuations, such as drought. Successful germination and establishment of new seedlings could be affected by changes to moisture conditions, lack of suitable germination sites, or competition with other plant species. The extent to which reproductive success of *G. penstemonoides* (i.e., persistence of populations and the species) depends on vegetative or sexual reproduction, pollinator dynamics, genetic variability, and gene flow is unknown. If *G. penstemonoides* is largely dependent on outcrossing for maximum seed set like other *Gilia* species, then any reductions in pollination efficiency could potentially reduce reproductive success. In addition, factors related to metapopulation dynamics, such as the amount of gene flow, genetic variability, inbreeding depression, and minimum viable population size, are unknown for *G. penstemonoides*. It is possible that peripheral occurrences, such as the population identified in Taylor River Canyon (Gunnison National Forest and private lands), may harbor rare alleles that are important to conserve for the long-term persistence of this species. The possibility of hybridization with other co-occurring *Gilia* species has not been fully assessed but is a possible threat, based on conservation issues raised for other rare species (e.g., Day 1965, Glenne 2003).

Management of the Species in USFS Region 2

Currently, there are no regulations or management actions specifically protecting populations of *Gilia penstemonoides* on USFS lands. In addition, quantitative demographic monitoring and studies on possible impacts from human land uses on *G. penstemonoides* populations and its habitat have not occurred. Based on the available information, we can only hypothesize how current and future management activities and other environmental influences may affect the abundance, distribution, and long-term persistence of this species.

Management implications

Most *Gilia penstemonoides* populations and habitat do not appear to be at immediate risk as a result of current management activities within the range. Cliff environments are generally at low risk for natural or human-influenced disturbances such as wildfires, blowdowns, prescribed fires, timber harvest, structure construction, mining, or off-road recreational use. However, specific populations and suitable habitat could be at risk for damage from rock climbing, trampling on cliffside trails, road creation involving rock blasting, mining activities, reservoir creation or expansion, introduction of invasive plant species, or changes to natural disturbance regimes. Priority conservation tools for this species may include monitoring the effects of current USFS Region 2 land-use practices and management activities, reducing any human-related threats to existing high-risk populations, assessing population trends, and monitoring and assessing the effects of environmental fluctuations. Additional key conservation tools may include surveying high probability habitat for new populations, preventing non-native plant invasions, studying demographic parameters and reproductive ecology, and assessing the effects of future management activities or changes in management direction.

Continued human avoidance of occupied habitat may be the best conservation strategy for *Gilia penstemonoides*. Some examples of other management practices that would protect *G. penstemonoides* habitat and minimize possible plant destruction by human-related activities include re-routing any trails away from existing populations, encouraging hikers, rock climbers, and tourists at viewpoints to stay on trails, regulating rock climbing in areas with *G. penstemonoides* populations, restricting off-road vehicle traffic, preventing the spread and establishment of non-native invasive species, regulating livestock activities to avoid areas with potential populations of this species, and monitoring reservoir water levels in areas near populations. Management decisions could also consider the effect of management activities on landscape fragmentation or barriers to dispersal, erosion/deposition, pollinator habitat, and introduction of invasive species.

Conservation elements

Despite its high regional endemism, the small number of recorded populations, and its low abundance, most *Gilia penstemonoides* populations currently appear to be at low risk for drastic declines or habitat destruction under current management. The factors affecting establishment, growth, and reproduction of this gilia are not well known. Features of *G. penstemonoides* biology that may be important to consider when addressing conservation of this species (i.e., key conservation elements) include its specialization on cliff habitats, possible poor competitive abilities, preference for suitable crevices within its cliff environments, potential reliance on adequate moisture availability, possible need for water movement to disperse seeds, scattered distribution of both individuals and populations, susceptibility to erosion and other cliff face disturbances, possible outcrossing needs requiring efficient pollination, and apparently low reproductive success. Any activity that created a barrier to dispersal, physically disturbed established plants, or damaged potential habitat could negatively impact *G. penstemonoides*. Other limiting factors may include competition from native or non-native species, changes to hydrological patterns altering moisture availability, global climate changes, inadequate pollination to ensure cross-fertilization, and genetic isolation of disjunct populations. The lack of information regarding the colonizing ability, susceptibility to herbivory, adaptability to changing environmental conditions, sexual and vegetative reproductive potential, and genetic variability of this species makes it difficult to predict its long-term vulnerability.

Tools and practices

Little is known about the biology, ecology, and spatial distribution of *Gilia penstemonoides*. Grey's 1982 studies are an important first step in obtaining an understanding of the biological and ecological needs for this species; additional long-term monitoring will build on this information base. Additional habitat surveys, quantitative population inventories and monitoring, and ecological studies are priorities for constructing a conservation plan. Inventories are useful for re-locating historical populations, estimating current abundance, and identifying high-quality populations. Surveys will help to locate any undiscovered populations. Quantitative monitoring will help obtain data for population trend and demographic modeling and assess the effects of management activities. Short-term research studies (e.g., genetic analyses, pollination studies) and long-term research studies (e.g., effects of environmental fluctuations) can supplement the current biological knowledge of this species and help estimate long-term persistence.

Species inventory and habitat surveys

Existing reports of *Gilia penstemonoides* populations (e.g., Peterson 1981, Grey 1982, Colorado Natural Heritage Program 2002, Johnston 2002) provide a useful information base, but the distribution and total abundance of this species is not sufficiently known to formulate regional conservation strategies. Fourteen occurrences have not been observed since 1995, and nine occurrences do not have any abundance information at all. Since 1982, additional populations have been discovered and more populations probably have yet to be discovered (Johnston 2002). Several researchers suggested that *G. penstemonoides* is probably more abundant than currently known and the actual distribution and abundance of the species may be underestimated (G. Austin personal communication 2002, R. Bingham personal communication 2002, Colorado Natural Heritage Program 2002, Johnston 2002). Additional surveys of potential habitat are needed to discover any additional populations and to document the full spatial extent of this species. For example, populations of *G. penstemonoides* may exist in areas within its range that have not been intensively surveyed (e.g., other canyons of the Rio Grande River basin).

The distribution of *Gilia penstemonoides* is scattered, with populations clustered in canyons over the range (**Figure 1**). This pattern is probably a combination of preference for canyon walls, habitat heterogeneity (i.e., variability in the habitat suitability over space), and undocumented populations. Within any one canyon, though, the distribution of this gilia may be more continuous. Because *G. penstemonoides* appears to grow on specific substrates and topographies throughout its range, researchers could identify areas of potential habitat using topographic maps, geologic maps, aerial or satellite images, and existing Geographic Information System (GIS) databases (i.e., Colorado NHP database). Peterson (1981) mapped existing populations on U.S. Geological Survey 7.5-minute topographic maps. New surveys could use existing populations as a starting point, because habitat zones may extend along the length and height of a canyon wall. Identifying new populations in steep terrain may be impossible without the use of rappelling techniques. Future surveys could include canyons with topography and parent material similar to existing populations. Grey (1982) suggested that several major tributaries below the BCGNP (e.g., Smith Creek and Crystal Creek) have topography similar to existing habitat areas and could provide appropriate habitat for this species. Grey (1982) surveyed volcanic cliffs within the West Elk Mountains and found that they were either unsuitable habitat or that *G. penstemonoides* had not dispersed into the area. In addition, locations upslope, downslope, upwind, and downwind from existing populations should be surveyed because *G. penstemonoides* seeds are most likely wind, water, and gravity dispersed. Grey (1982) also suggested further studies of the substrate and microsite environment to understand the ecological needs of this species. The Colorado NHP and NatureServe have developed databases and GIS components to assist in habitat modeling (D. Anderson personal communication 2003).

Once located, the size and extent of *Gilia penstemonoides* populations could be mapped, labeled, and recorded using global positioning system (GPS) and GIS technology. Mapping the extent of each known population of this species will maintain consistency for future observations, facilitate information sharing between different management organizations, and help in making estimates of density and abundance. Mapping exercises will also elucidate the spatial distribution of populations at the local and regional levels and provide a framework for creating a metapopulation study. High-quality populations in pristine habitat could be identified. Populations in areas slated for various management, maintenance, or disturbance activities could be readily identified. A detailed assessment could be undertaken before activities such as mining or reservoir creation occur.

Population monitoring and demographic studies

Although Grey (1982) performed preliminary studies on the population biology of six *Gilia penstemonoides* populations, additional information is needed to gain an understanding of the life cycle, demography, and population trends of this species. Information is lacking on longevity, germination requirements, seed survival in the field, extent of asexual reproduction, factors affecting flower development, pollination ecology, role of the seed bank, and gene flow between populations. This type of species-specific information would be useful in assessing threats to this species and estimating species viability. For example, seed bank studies could assess the abundance of seeds to reveal dispersal patterns in this species. Studies of germination needs in the field might elucidate potential limiting factors for the establishment of new individuals.

Researchers have noted the existence of several *Gilia penstemonoides* populations over time, but no long-term demographic studies or population trend monitoring have been initiated. Grey (1982) acknowledged that to gain more knowledge on the reproductive success of populations and their age class composition requires long-term study. Long-term monitoring studies could yield helpful information, such as temporal and spatial patterns of abundance and dormancy; environmental factors that influence abundance (e.g., drought); whether populations are increasing, decreasing, or remaining stable; and the minimum number of plants necessary to perpetuate the species. Schemske et al. (1994) recommended that the most biologically relevant question in evaluating the status of rare plants is whether population size is increasing, decreasing, or remaining stable under current conditions. Even the collection of simple metrics, such as those collected during Grey's 1982 study, would greatly augment the current understanding of distribution and basic biological information about this species. For example, researchers could record population size, area, and density, as well as the presence of different age classes at each population. Identifying life history stages and performing an annual census of each stage are the first priorities in estimating the rate and direction of population growth (Schemske et al. 1994). Related demographic questions that may also be addressed using these techniques include the rates of survival, longevity, and recruitment, population fluctuations from year to year, and the age at which individuals become reproductive. Grey (1982) studied germination success and found that seed viability is low, especially after eight months of storage. The implications of possible low seed viability on reproductive success for this species in the field have not been studied.

The specialization of *Gilia penstemonoides* on steep and inaccessible cliffs makes it difficult to survey for plants and even harder to assess population sizes (Johnston 2002). Grey (1982) found that the steep canyon walls made it difficult to apply standard sampling techniques to *G. penstemonoides* populations, so he used a point-line transect to sample accessible populations and an adapted point-centered quarter method for less accessible areas (Grey 1982). He suggested that additional monitoring could use rappelling techniques and modified sample plots to access more populations; Larson and Batson (1978) used these techniques when describing rock face vegetation in the southeastern United States.

Several groups have developed protocols for monitoring population and demographic trends of rare plant species. These protocols can be easily accessed and used to develop specific monitoring plans for use in USFS Region 2. For example, Elzinga et al. (1998) and Hutchings (1994) are general references that provide concrete guidance on designing and implementing quantitative monitoring plans for rare plant species. In addition, population matrix models that measure individual fitness and population growth provide flexible and powerful metrics for evaluating habitat quality and identifying the most critical feature of the life history of a species (Hayward and McDonald 1997). Deterministic demographic models of single populations are the simplest analyses and are powerful tools in making decisions for managing threatened and endangered species (Beissinger and Westphal 1998).

Habitat monitoring and management

Potential habitat changes within *Gilia penstemonoides* environments and the response of this species to those changes are not well known. The types of monitoring studies required to understand how this species responds to environmental fluctuations or to changes in the disturbance regime would be complex and could take decades. For example, precipitation fluctuations have the potential to affect adult plant survival, weathering rates, germination success, pollinator population trends, timing of flowering, and/or growth of surrounding vegetation. It will be very difficult to determine to what extent disturbances (e.g., erosion, weathering) affect populations and whether competing plant species would result in local extirpation of a population.

Habitat management could also consider issues related to the surrounding landscape, such as pollinator habitat needs, trail proximity and position in relation to population locations, and reservoir water lines in relation to population locations.

Biological and ecological studies

Much of the information regarding habitat requirements, establishment, reproduction, dispersal, relationship with herbivores, competition with other species, and overall persistence has not been studied for *Gilia penstemonoides*. Grey (1982) described his methodology (e.g., site surveying, habitat characterization, population sampling, reproductive assessments, germination trials, and viability tests) and identified areas for further research. In specific, he suggested studying the root zone and substrate environment, identifying the most efficient pollinators, monitoring effects of land use, and studying the effects of spring snowmelt and precipitation on development. Further studies through cross-breeding tests, chromosome analyses, and chromatography would help verify the presence of possible hybridization between *G. penstemonoides* and *G. pinnatifida* (Grey 1982, D. Culver personal communication 2003). Refer to Grey (1982) for details on collecting and preparing seeds for germination trials with cold stratification, scarification with concentrated sulfuric acids, and dark conditions.

Availability of reliable restoration methods

Aside from Grey's 1982 germination trials, there has been no published research to date involving the production of *Gilia penstemonoides* in greenhouse environments or the storage of seed for use in restoration projects. Grey (1982) found that seed viability was low after eight months of storage. The steep, canyon wall habitats of *G. penstemonoides* generally cannot be restored or altered, except through activities like rock blasting and reservoir creation or expansion. Restoration of populations on inaccessible existing habitat would need to consider the use of rappelling techniques to access cliff face crevices. There are still too many unknowns regarding habitat preferences and basic population dynamics to know which factors are critical in restoring this species.

Information Needs and Research Priorities

Based on our current understanding of *Gilia penstemonoides*, we can identify research priorities where additional information will help to develop management objectives, initiate monitoring and research programs, and form a conservation plan. To address these data gaps, information can be obtained through surveys, long-term monitoring plans, and research programs. There is so little known about the biology and ecology of this species that there are a large number of research projects that could be implemented.

Identifying high-quality populations and populations that may be immediately threatened, monitoring population trends, researching the effects of environmental fluctuations, surveying for new populations, and studying basic biological traits are of primary importance to further the understanding of *Gilia penstemonoides* in USFS Region 2. The following types of studies would supplement basic knowledge regarding this species:

- ❖ Re-visiting and detailed mapping and inventory of existing populations
- ❖ Monitoring population trends
- ❖ Identifying high-quality populations and habitats
- ❖ Surveying for new populations
- ❖ Identifying any imminent threats to known populations, especially those related to rock-climbing
- ❖ Characterizing and measuring microhabitats
- ❖ Conducting studies related to reproductive biology, including pollinator surveys, germination, vegetative reproduction, mycorrhizal associations, and seedbank analyses
- ❖ Identifying possible causes of individual plant mortality (e.g., water stress, herbivory)
- ❖ Assessing gene flow, genetic variability, and possible hybridization throughout range.

Additional research and data that may be useful but are not incorporated into this assessment include aspects related to managing data for efficient use. Data acquired during surveys, inventories, monitoring programs, and research projects are most easily accessible if they are entered into an automated relational database. Databases also facilitate the sharing of information to all interested parties. The Colorado NHP and NatureServe have developed databases and GIS components to assist in information storage and habitat modeling (D. Anderson personal communication 2003). Such databases should be integrated with GIS and allow activities such as the following:

- ❖ Efficient incorporation of data in the field
- ❖ Documentation and cataloging herbarium specimens
- ❖ Generation of location and habitat maps
- ❖ Characterization of associated habitats, including geologic substrates
- ❖ Identification of population trends over time
- ❖ Identification of data gaps that require further information gathering
- ❖ Easy modification as additional information becomes available.

DEFINITIONS

Annual – A plant that completes its entire life cycle (germinates, flowers, sets seed, and dies) in a single growing season.

Anthesis – A stage in floral development when the flower is open and sheds pollen.

Apomixis – The ability of some plant species to reproduce asexually with seeds.

Asexual reproduction – Any form of reproduction not involving the union of gametes.

Basal leaves – Leaves that are attached near the ground; compared to cauline leaves that are on the stem above the ground.

Caespitose – Grows in tufts; in low-branching pattern from near base.

Caudex – Short, swollen, often woody portion of a plant stem that is at or beneath ground level on top of a taproot. This structure functions in new stem production, serves as a storage organ, and/or produces short rhizomes.

Cauline leaves – Leaves that are attached on the stem above the ground; compared to basal leaves present at ground level.

Corolla – The portion of a flower comprised of petals.

Cross-breeding – Sexual reproduction between two individuals with different genetic composition.

Cross-fertilization – Fusion of gametes from two different organisms.

Cross-pollination – The transfer of pollen from an anther of one flower on one plant to the stigma of a different flower on a different plant of the same species. Cross-pollination involves the action of a pollinating agent to effect transfer of the pollen.

Cymose inflorescence – A type of flowering shoot where the first formed flower develops from the tip of the growing shoot and other flowers form on lateral buds beneath.

Demographics – The study of fecundity and mortality parameters that are used to predict population changes.

Disjunct – A geographically isolated population or species outside of the range of other similar populations or species.

Dormancy – A period of growth inactivity in seeds, buds, bulbs, and other plant organs even when environmental conditions normally required for growth are met.

Endangered – Defined in the Endangered Species Act as a species, subspecies, or variety likely to become extinct in the foreseeable future throughout all of its range or extirpated in a significant portion of its range.

Endemic – A population or species with narrow physiological constraints or other restrictions, which limit it to a special habitat or a very restricted geographic range, or both.

Entire – Having a margin that lacks any toothing or division, as on the leaves of some plants.

Exserted – Projecting beyond another structure.

Fertility – The reproductive capacity of an organism.

Fitness – Success in producing viable and fertile offspring.

Forb – An herbaceous plant, other than grasses, reeds, and sedges

Fruit – A mature ovary; contains seeds.

Funnelform – Funnel-shaped.

Genotype – The genetic constitution of an organism.

Glandular – Having glands, protuberances or depressions on the surface of an organ, which produce a sticky, greasy, or viscous substance.

Habitat fragmentation – The break-up of a continuous landscape containing large patches into smaller, usually more numerous, and less connected patches. Can result in genetic isolation.

Habitat isolation – When two or more habitats are separated (i.e., geographically) to an extent to prevent cross-breeding, thereby genetically isolating two parts of a once continuous population.

Herbaceous – Adjectival form of herb; an annual or perennial plant that dies back to the ground at the end of the growing season because it lacks the firmness resulting from secondary, woody growth.

Hybridization – The result of a cross between two taxa.

Inflorescence – A group of flowers attached to a common axis in a specific arrangement.

Mucilaginous – Relating to or secreting a moist and sticky substance.

Mycorrhiza – Symbiotic association between a fungus and the root of a higher plant.

Outcrossing – Sexual reproduction between two individuals with different genetic composition.

Ovary – The enlarged portion of the female reproductive structure (pistil) that contains the ovules and develops into the fruit.

Ovule – Part of "female" plant reproductive system that becomes a seed after fertilization.

Perennial – A plant that lives for three or more years and can grow, flower, and set seed for many years; underground parts may regrow new stems in the case of herbaceous plants.

Perfect flower – Flower with both "male" (stamens) and "female" (pistils) reproductive organs.

Petiole – Leaf stalk.

Phenotype – The external visible appearance of an organism.

Phenotypic plasticity – When members of a species vary in height, leaf size or shape, flowering (or spore-producing time), or other attributes with changes in light intensity, latitude, elevation, or other site characteristics.

Pinnately-lobed – Consisting of projecting appendages arranged in two rows along an axis.

Pinnatisect – A leaf that is divided into opposite pairs of lobes cut almost to the leaf mid rib.

Polyploidy – Having more than two complete sets of chromosomes per cell.

Population viability analysis – An evaluation to determine the minimum number of plants needed to perpetuate a species into the future, the factors that affect that number, and current population trends for the species being evaluated.

Rappel – To descend a cliff or mountainside by means of a double rope wrapped around the body.

Recruitment – The addition of new individuals to a population by reproduction.

Ruderal habitat – Temporary or frequently disturbed habitats.

Ruderal species – Species that can exploit low stress, high disturbance environments.

Salverform corolla – Having petals united in a slender tube at the base with abruptly expanding, flat lobes at the top.

Self-incompatible – Plants incapable of producing a fertile zygote through self-fertilization; can involve morphological structures or genetic mechanisms.

Self-pollination – The transfer of pollen from the anther of a flower to the stigma of the same flower, or between different flowers on the same plant.

Sexual reproduction – Reproduction involving the union of gametes.

Symbiosis – An intimate association between two dissimilar organisms that benefits both of them.

Sympatric – Occupying the same geographic region.

Threatened – Defined in the Endangered Species Act as a species, subspecies, or variety in danger of becoming endangered within the foreseeable future throughout all or a significant portion of its range.

Venter – The ventral, or underside, of the body.

Viability – The capability for living or continuing to develop.

Zygote – Cell formed from the union of two gametes.

References Used in Compiling Definitions of Terms

Gifford, E.M. and A.S. Foster. 1989. Morphology and evolution of vascular plants, third edition. W. H. Freeman and Co.: New York, NY.

Gleason, H.A. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. New York Botanical Garden: New York, NY.

National Invasive Species Council. 2003. Invasivespecies.gov: A gateway to Federal and State invasive species activities and programs [Online]. Department of the Interior, Washington, D.C. Available at http://www.invasivespecies.gov/.

Radford, A.E., W.C. Dickison, J.R. Massey, and C.R. Bell. 1974. Vascular Plant Systematics. Harper & Row: New York, NY.

Smith, J.P. 1977. Vascular Plant Families. Mad River Press: Eureka, CA.

Spackman, S., B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado Rare Plant Field Guide. Prepared for the Bureau of Land Management, U.S. Forest Service, and U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program, Fort Collins, CO.

Stearn, K.R. 1991. Introductory Plant Biology, fifth edition. Wm. C. Brown Publishers: Dubuque, IA.

Theobald, D.M. 1998. Tools Available for Measuring Habitat Fragmentation. Presented at the Colorado Chapter of The Wildlife Society Annual Meeting, Grand Junction, Colorado. January 22, 1998.

Weier, T.E., C.R. Stocking, and M.G. Barbour. 1970. Botany, An Introduction to Plant Biology. John Wiley & Sons: New York, NY.

Zomlefer, W. 1994. Guide to Flowering Plant Families. University of North Carolina Press: Chapel Hill, NC.

References

Austin, Gay. 2002. Rangeland management specialist, USFS Grand Mesa-Uncompahgre-Gunnison National Forest, Gunnison, CO. Personal communication.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology, second edition. The Benjamin/Cummings Publishing Company, Inc.: Menlo Park, CA.

Beissinger, S.R. and M.I. Westphal. 1998. On the use of demographic models of population viability in endangered species management. Journal of Wildlife Management 62(3):821-841.

Bingham, Robin. 2002. Assistant Professor of Biology, Western State College, Gunnison, CO. Personal communication.

Caswell, H. 2001. Matrix Population Models: Construction, Analysis, and Interpretation, second edition. Sinauer Associates, Inc, Sunderland, MA.

Colorado Natural Heritage Program. 2002. Biological Conservation Database: *Gilia penstemonoides*. Colorado Natural Heritage Program, Fort Collins, CO.

Culver, D. 2003. Ecologist, Colorado Natural Heritage Program, Fort Collins, CO. Personal communication.

Day, A. 1965. The evolution of a pair of sibling allotetraploid species of cobwebby *Gilias* (Polemoniaceae). El Aliso 6(1):25-75.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. Technical Reference 1730-1. Bureau of Land Management, Denver, CO.

Erhard, Dean. 2002. Ecologist, USFS Rio Grande National Forest, Monte Vista, CO. Personal communication.

Fertig, W. and B. Heidel. 2002. Wyoming Plant Species of Special Concern [Online]. Unpublished report prepared by the Wyoming Natural Diversity Database, Laramie, WY. Available at http://www.uwyo.edu/wyndd.

Glenne, G. 2003. Reproductive biology, hybridization isolating mechanisms, and conservation implications of two rare subspecies of *Penstemon bicolor* (Brandeg.) Clokey and Keck: ssp. *bicolor* and ssp. *roseus* Clokey and Keck (Scrophulariaceae *S.L.*) in Clark County, Nevada. M.S. Thesis, Utah State University, Logan, UT.

Grant, V. 1959. Natural History of the Phlox Family, Volume 1 Systematic Botany. Martinus Nijhoff: The Hague.

Grant, V., and K.A. Grant. 1965. Pollination in the Phlox Family. Columbia University Press: New York, NY.

Grey, W.F. 1982. Population and habitat analyses of two endemic Colorado plants under guidelines of the Endangered Species Act of 1973. Ph.D. Dissertation, University of Northern Colorado, Greeley, CO.

Grime, J.P. 1979. Plant Strategies and Vegetation Processes. John Wiley & Sons, Ltd: Bath, U.K.

Harmon, W. and W. Grey. 1980. Field Data Summary: *Gilia penstemonoides*. Unpublished.

Harrington, H.D. 1954. Manual of the Plants of Colorado, second edition. Sage Books: Denver, CO.

Hartman, R.L. and B.E. Nelson. 2001. A Checklist of the Vascular Plants of Colorado [Online]. Unpublished report prepared by the Rocky Mountain Herbarium, Laramie, WY. Available at http://www.rmh.uwyo.edu.

Hayward, G.D. and D.B. McDonald. 1997. Matrix population models as a tool in development of habitat models. In: J.R. Duncan,, D.H. Johnson, and T.H. Nicholls, editors. Biology and Conservation of Owls in the Northern Hemisphere, 2nd International Symposium, February 5 to 9, Winnipeg, MB. General Technical Report NC-190, U.S. Department of Agriculture, USFS.

Hutchings, M.J. 1994. Monitoring plant populations: census as an aid to conservation. Pages 61-72 in F.B. Goldsmith, editor. Monitoring for Conservation and Ecology. Chapman and Hall: New York, NY.

Integrated Taxonomic Information System. 2002. Integrated Taxonomic Information System Database [Online]. Available at http://www.itis.usda.gov.

Johnston, B. 2002. Region 2 sensitive species evaluation form for *Gilia penstemonoides*. USFS Region 2, Lakewood, CO.

Johnston, Barry. 2003. Ecologist, USFS Grand Mesa-Uncompahgre-Gunnison National Forest, Gunnison, CO. Personal communication.

Jones, M.E. 1893. Contributions to Western Botany. Zoe 4:279-280.

Kansas Natural Heritage Inventory. 2000. Rare Plants of Kansas. Kansas Natural Heritage Inventory, Kansas Biological Survey, Lawrence, KS. Available at http://www.kbs.ku.edu/.

Kaye, T.N. 1997. Seed dormancy in high elevation plants: Implications for ecology and restoration. In: T.N. Kaye, A. Liston, R.M. Love, D.L. Luoma, R.J. Meinke, and M.V. Wilson, editors. Conservation and Management of Native Plants and Fungi. Native Plant Society of Oregon, Corvallis, OR.

Larson, S.S. and W.T. Batson. 1978. The vegetation of vertical rock faces in Pickens and Greenville Counties, South Carolina. Castanea 43(4):255-260.

McMillan, M.A. and D.W. Larson. 2002. Effects of rock climbing on the vegetation of the Niagara escarpment in Southern Ontario, Canada. Conservation Biology 16(2):389-398.

NatureServe. 2003. NatureServe Explorer: An online encyclopedia of life, Version 1.7 [Online]. NatureServe, Arlington, VA. Available at http://www.natureserve.org/explorer.

Nebraska Natural Heritage Program. 2001. Nebraska Plants of Special Concern. Nebraska Natural Heritage Program, Lincoln, NE.

O'Kane, S.L. 1988. Colorado's Rare Flora. Great Basin Naturalist 48(4):434-484.

Office of the Secretary of Interior. 1964. Wilderness Act of September 3, 1964. P.L.88-577, 78 Stat. 890; 16 U.S.C. 1121 (note), 1131-1136.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Peterson, J.S. 1981. Status Report: *Gilia penstemonoides*. Colorado Natural Heritage Inventory, Colorado Natural Areas Program, Department of Natural Resources, Denver, CO.

Porter, J.M. 1998. *Aliciella*, A recircumscribed genus of Polemoniaceae. Aliso 17(1):23-46.

Porter, J.M. 2000. Polemoniaceae of Colorado [handout]. Prepared for a Colorado Native Plant Society workshop, February 26-27.

Schemske, D.W., B.C. Husband, M.H. Ruckelshaus, C. Goodwillie, I.M. Parker, and J.G. Bishop. 1994. Evaluating approaches to the conservation of rare and endangered plants. Ecology 75(3):584-606.

South Dakota Natural Heritage Program. 2002. Rare, Threatened, and Endangered Plant Species Tracked by the South Dakota Natural Heritage Program. South Dakota Department of Fish, Game, and Parks, Pierre, SD.

Spackman, S., B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado Rare Plant Field Guide. Prepared for the Bureau of Land Management, U.S. Forest Service, and U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program, Fort Collins, CO.

University of Colorado Herbarium. 2002. Colorado Vascular Plant Specimen Database. University of Colorado, Boulder, CO.

U.S. Bureau of Land Management. 1996. BLM Manual 6840 (Special Status Species Management). BLM Manual, U.S. Department of Interior, Washington, D.C.

U.S. Bureau of Land Management. 2000. Colorado BLM State Director's Sensitive Species List (Animals and Plants) [Online]. BLM, Colorado State Office, Lakewood, CO. Available at http://www.co.blm.gov/botany/sens_species.htm.

U.S. Congress. 1982. The National Environmental Policy Act of 1969, as amended 1982. U.S. Congress, Washington, D.C. Available at http://ceq.eh.doe.gov/nepa/regs/nepa/nepaeqia.htm.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2003. The PLANTS Database, Version 3.5 [Online]. National Plant Data Center: Baton Rouge, LA. Available at http://plants.usda.gov.

U.S. Fish and Wildlife Service. 1973. Endangered Species Act. 16 U.S.C. 1531-1536, 1538-1540.

U.S. Fish and Wildlife Service. 1980. Endangered and threatened wildlife and plants: Review of plant taxa for listing as endangered or threatened species. Federal Register 45(242):82480-82569.

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants: Review of plant and animal taxa for listing as endangered or threatened species. Federal Register 58(188):51144-51190.

U.S. Fish and Wildlife Service. 1996. Endangered and threatened wildlife and plants: Review of plant and animal taxa that are candidates for listing as endangered or threatened species; Notice of Review; Proposed Rule. Federal Register 61(40):7596-7613.

U.S. Forest Service. 1993. Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region [Online]. Available at http://roadless.fs.fed.us/documents/feis/data/sheets/summspd/tes_supp/r2_ssspecies.pdf.

U.S. Forest Service. 1995. Title 2600 - Wildlife, Fish, and Sensitive Plant Habitat Management. USFS Forest Service Manual, Amendment No. 2600-95-7. U.S. Department of Agriculture, Washington, D.C.

U.S. Forest Service. 2003. Supplement no. 2600-2003-1. Chapter 2670 – Threatened, Endangered, and Sensitive Plants and Animals. USFS Forest Service Manual, FSM 2600 - Wildlife, Fish, and Sensitive Plant Habitat Management. U.S. Department of Agriculture, Rocky Mountain Region (Region 2), Denver, CO.

U.S. Forest Service and Bureau of Land Management. 2000. Environmental Assessment: Gunnison Travel Interim Restrictions. U.S. Department of Agriculture, USFS, Grand Mesa, Uncompahgre, and Gunnison National Forests, Delta, CO and U.S. Department of Interior, BLM, Gunnison and Uncompahgre BLM Field Offices, Gunnison, CO. Available at http://www.fs.fed.us/r2/gmug/policy/gunn_travel/final_ea.pdf.

U.S. National Park Service. 2002. U.S. National Park Service Research Permit and Reporting System [online]. U.S. Department of the Interior, NPS, Washington, D.C. Available at https://science1.nature.nps.gov/research/ac/ResearchIndex.

Weber, W.A. and R.L. Wittmann. 2000. Catalog of the Colorado Flora: A Biodiversity Baseline [Online]. University of Colorado, Boulder, CO. Available at http://cumuseum.colorado.edu/Research/Botany/Databases/catalog.html.

Weber, W.A. and R.L. Wittmann. 2001a. Colorado Flora: Eastern Slope, third edition. University of Colorado Press, Boulder, CO.

Weber, W.A. and R.L. Wittmann. 2001b. Colorado Flora: Western Slope, third edition. University of Colorado Press, Boulder, CO.

Zomlefer, W. 1994. Guide to Flowering Plant Families. University of North Carolina Press: Chapel Hill, NC.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, DC 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.